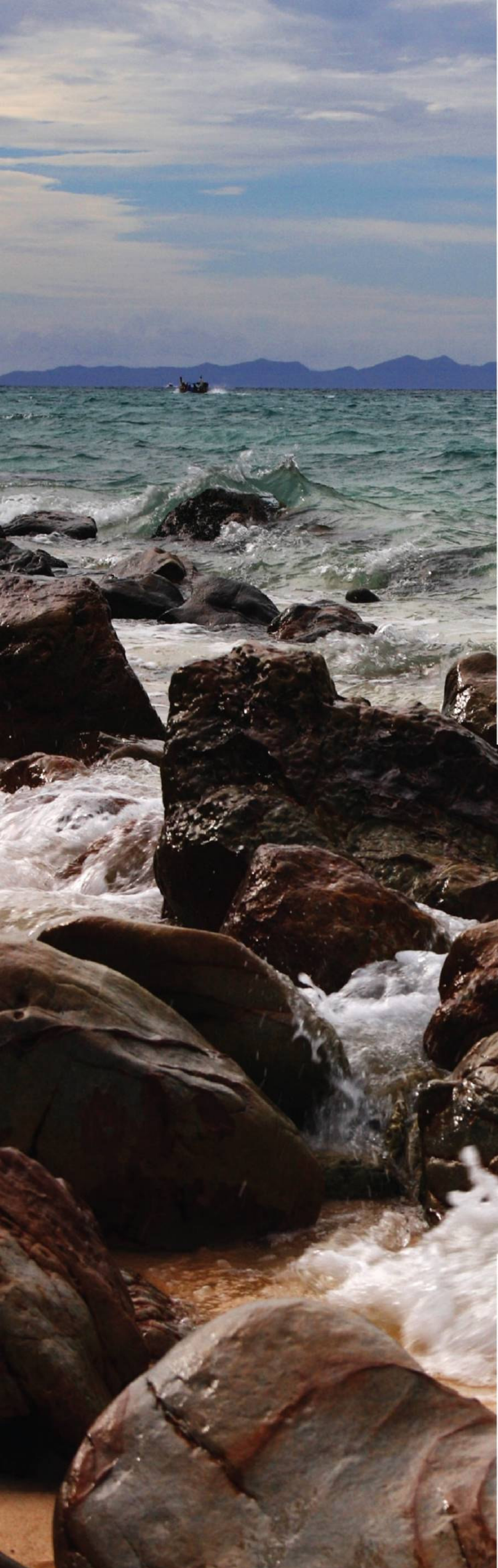

Hartlepool Borough Council

Level 2 Strategic Flood Risk Assessment

Final Report
October 2010

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Contract

This report describes work commissioned by Tom Britcliffe, on behalf of Hartlepool Borough Council, by an email dated 15/04/10. Hartlepool Borough Council's representative for the contract was Tom Britcliffe. Sam Wingfield and Sam Willis of JBA Consulting carried out this work.

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Purpose

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JBA would like to thank Dennis Hancock and Tom Britcliffe who assisted in the production of this report.

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1. Introduction

1.1 Background

JBA Consulting was commissioned in April 2010 by Hartlepool Borough Council (Hartlepool BC) to undertake a Level 2 Strategic Flood Risk Assessment (SFRA). The Level 1 SFRA was finalised in May 2010. This Level 2 SFRA focuses of providing greater detail for those sites shown to be at high risk of tidal flooding, between the Tees Estuary and Seaton Carew and for the Hartlepool Hospital and high risk of fluvial flooding at the Industrial Estate sites. The Level 2 SFRA has also undertaken a more detailed assessment and confirmation of Critical Drainage Areas (CDAs).

The Level 1 and 2 SFRAs for Hartlepool BC have been prepared in accordance with current best practice, Planning Policy Statement 25 Development and Flood Risk[1] and the PPS25 Practice Guide[2]. This document comprises the Level 2 assessment.

1.2 Scope and objectives

1.2.1 Exception and Sequential Tests

The Hartlepool BC Level 1 SFRA has provided sufficient data and information to inform the application of the Sequential Test. This information was based on current available information, including:

- Flood Zone maps
- Hydraulic modelled flood outlines
- Flood risk management measures maps
- Surface water flooding maps
- Climate change maps

Where sites have been identified in areas at risk of flooding, the Sequential Test should aim to move these sites to areas of lower flood risk or replace them with a lower vulnerability land use.

If this is not possible and there is justification for developing in an area at risk of flooding, sites within Flood Zone 2 can be allocated subject to a flood risk assessment (FRA). Employment sites within Flood Zone 3 can also be allocated subject to an FRA but for residential purposes, the Exception Test needs to be passed. It is recommended within this study that employment sites within Flood Zone 3 should also undergo the Exception Test, as land use can be changed at a later date and because it is good practice to complete this test for any development which is shown to be at a high risk of flooding.

The requirements of the Exception Test are displayed below:

a. It must be demonstrated that the development provides wider sustainability benefits to the community that outweigh flood risk, informed by a SFRA where one has been prepared. If the LDD has reached the 'submission' stage (see Figure 4.1 of PPS12: Local Development Frameworks) the benefits of the development should contribute to the Core Strategy's Sustainability Appraisal (SA);
b. The development must be on developable previously-developed land or, if it is not on previously-developed land, that there are no reasonable alternative sites on developable previously-developed land; and
c. A site-specific Flood Risk Assessment must demonstrate that the development will be safe, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

[1] CLG (2010) PPS25: Development and Flood Risk
[2] CLG (2009) PPS25: Development and Flood Risk Practice Guide

A number of proposed development sites (residential and employment) are shown to be at risk of tidal flooding within Hartlepool BC as well as a proposed mixed use development which is shown to be at risk of fluvial flooding. This Level 2 SFRA will provide the evidence to show whether these sites are likely to pass the Exception Test namely part c) can the site be developed in a safe and sustainable manor.

Whilst the Exception Test process makes it possible to justify areas where developments can be built safely, it must not been seen as an opportunity to place inappropriate development in flood risk areas.

In order to establish whether applying the Exception Test is justified and sites can be developed safely, the Level 2 SFRA considers the detailed nature of flood hazard within the Flood Zone itself. Flood hazards include:

- Flood probability;
- Flood depth;
- Flood Velocity; and
- Rate of onset of flooding.

These factors can be significantly affected by the presence of flood defences or any other infrastructure which acts as a flood defences. Flooding behind such infrastructure can occur either as a result of:

- Constructional or operation failure of the defence, either in whole or in part (breach);
- Water levels rising to exceed the level of the defence (overtopping); or
- Overloading of the surface water drainage system, either due to its own limited capacity, or being unable to discharge due to high water levels outside the defended area.

By facilitating the application of the Exception Test, the Level 2 SFRA technical work will also provide supporting evidence to the possible mitigation measures that would enable the development to proceed.

1.3 Study Area to be Assessed

1.3.1 Tidal flood risk sites

The Level 1 SFRA identified a number of sites, predominantly employment use, at risk of tidal flooding in Hartlepool BC. These sites are shown to be within Flood Zone 3 and extend from the Tees Estuary at Greatham Creek, round the open coastline to Seaton Carew (see Figure 1-1).

An initial assessment during the Level 1 SFRA showed that the current Environment Agency's Flood Map may be over estimating the tidal flood extent in this area. This is because these extents are based on tidal flood level predictions that have now been improved. These extents were also produced using a broad scale digital elevation model; more detailed LIDAR data is now available for this area.

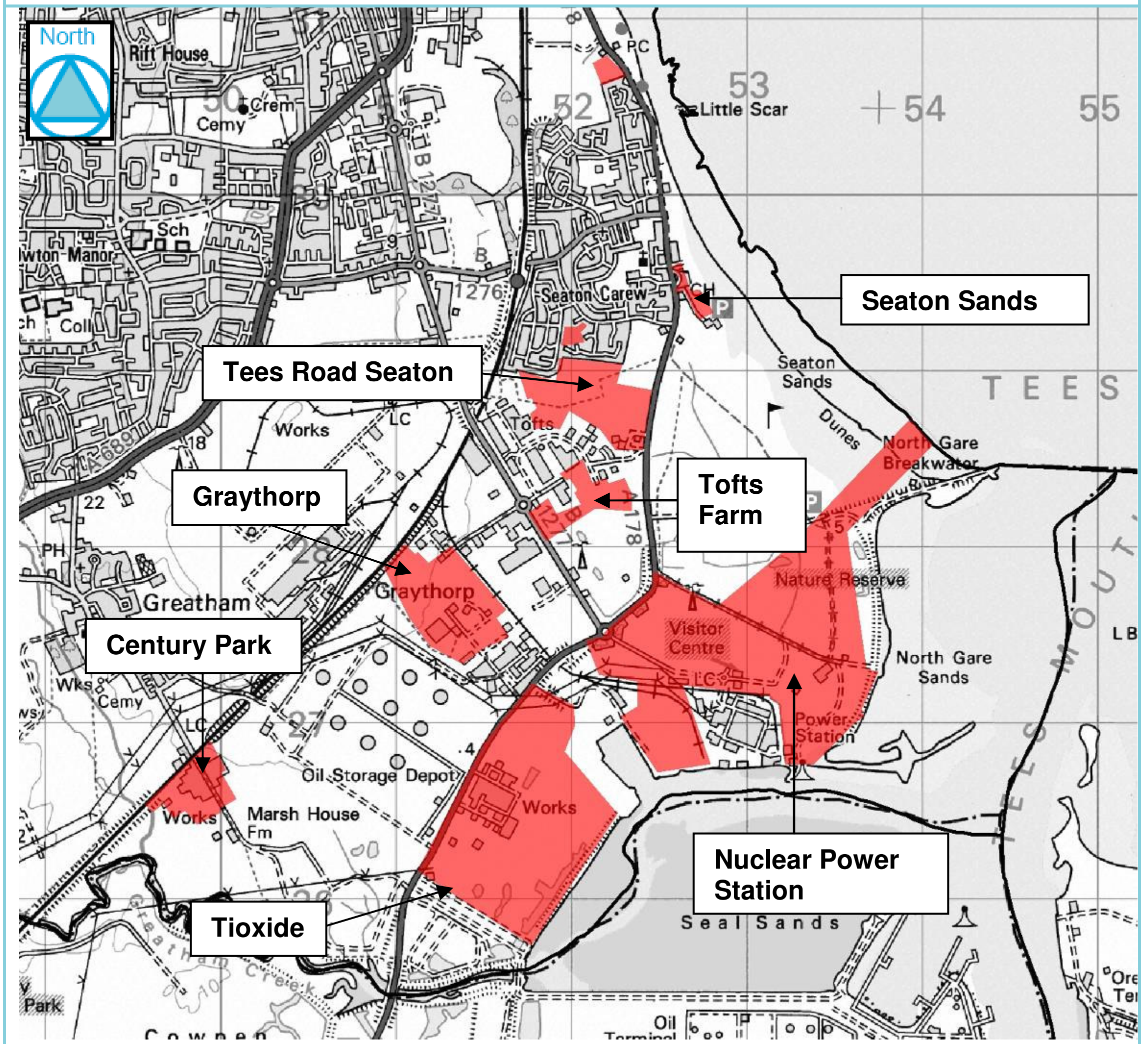
This Level 2 SFRA has constructed a 2D tidal model which has provided a more accurate representation of tidal flood risk in this area. For the sites still shown to be at risk, the new modelling allows an assessment of flood depth and hazard to be made and assess whether the sites will be safe for development (following the Sequential Test). This information can also be used to identify appropriate flood risk management measures required in order to bring the sites forward for development. This information will inform the Local Development Framework (LDF) and the policies and proposals produced for the developments.

Figure 1-1 identifies the tidal flood risk sites that will be assessed.

- The Tioxide site represents the existing chemical works and the operational land under Huntsman Tioxide's ownership. The chemical works here has recently been extended. There are no short to medium term plans for further expansion but this land remains within Huntsman Tioxide's ownership and parts of it may be further developed in the long-term.

- The nuclear power station site is the area that could potentially be developed as one of the ten government approved nuclear power station sites. This land surrounds the existing nuclear power station which is due to be decommissioned.
- Century Park, Graythorp, Tofts Farm and Tees Road Seaton are all proposed industrial sites.
- Seaton Sands is a proposed mixed use (commercial/leisure/tourism/residential) development.

Figure 1-1: Sites at risk of tidal flooding



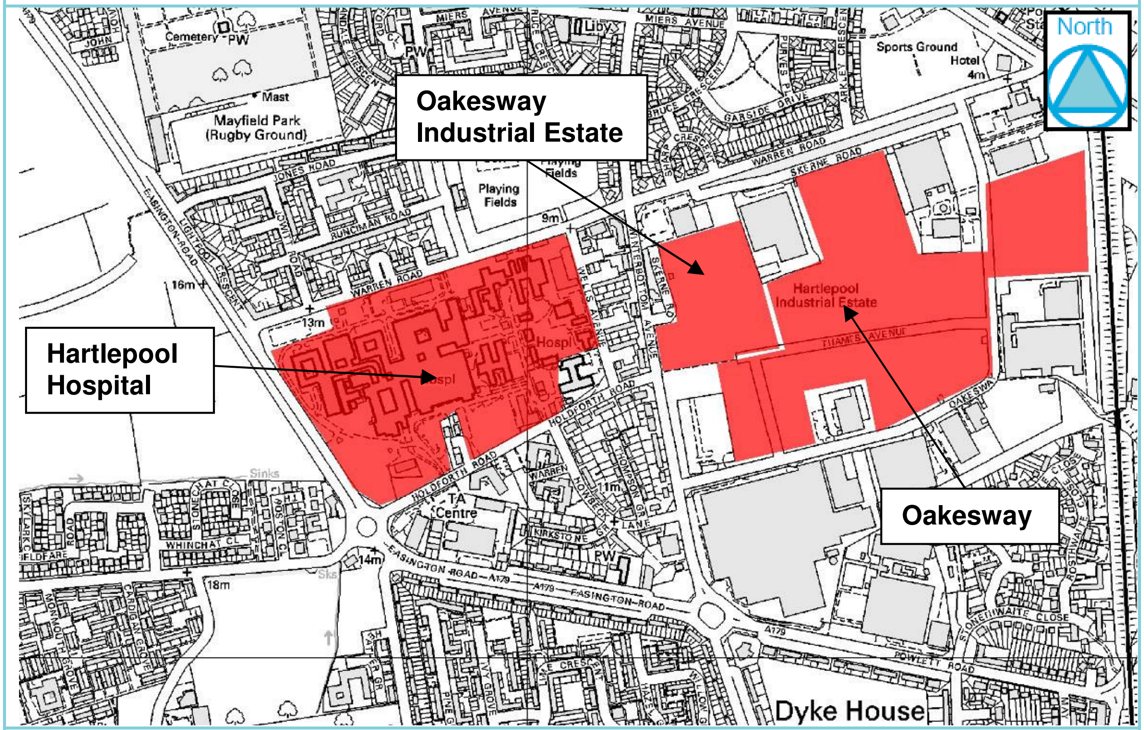
1.3.2 Flood Risk to Hartlepool Hospital and Industrial Estate

The Level 1 SFRA identified that the Hartlepool Hospital and Hartlepool Industrial Estate proposed development sites (see Figure 1-2) are within Flood Zones 2 and 3. The Flood Zones here have been derived through a generalised modelling method and are associated with a watercourse that passes through the new Middle Warren development. For this study, this watercourse has been named Middle Warren Watercourse. The Level 1 assessment concluded that the Flood Zones associated with this watercourse need updating, using more detailed modelling methods.

Due to the urban nature of this watercourse, the Level 1 SFRA concluded that flood risk here is complex as it involves a number of combined sewers and culverted reaches. The Scope of the Level 2 SFRA therefore included gathering more detailed information on the flood risk, including information on the contributing drainage system and new detailed flood flow analysis on the watercourse as it becomes culverted at Hartlepool Hospital.

Evidence for the Exception Test will be presented if the proposed development allocations are still shown to be at risk of flooding after the analysis.

Figure 1-2: Hartlepool Hospital and Industrial Estate



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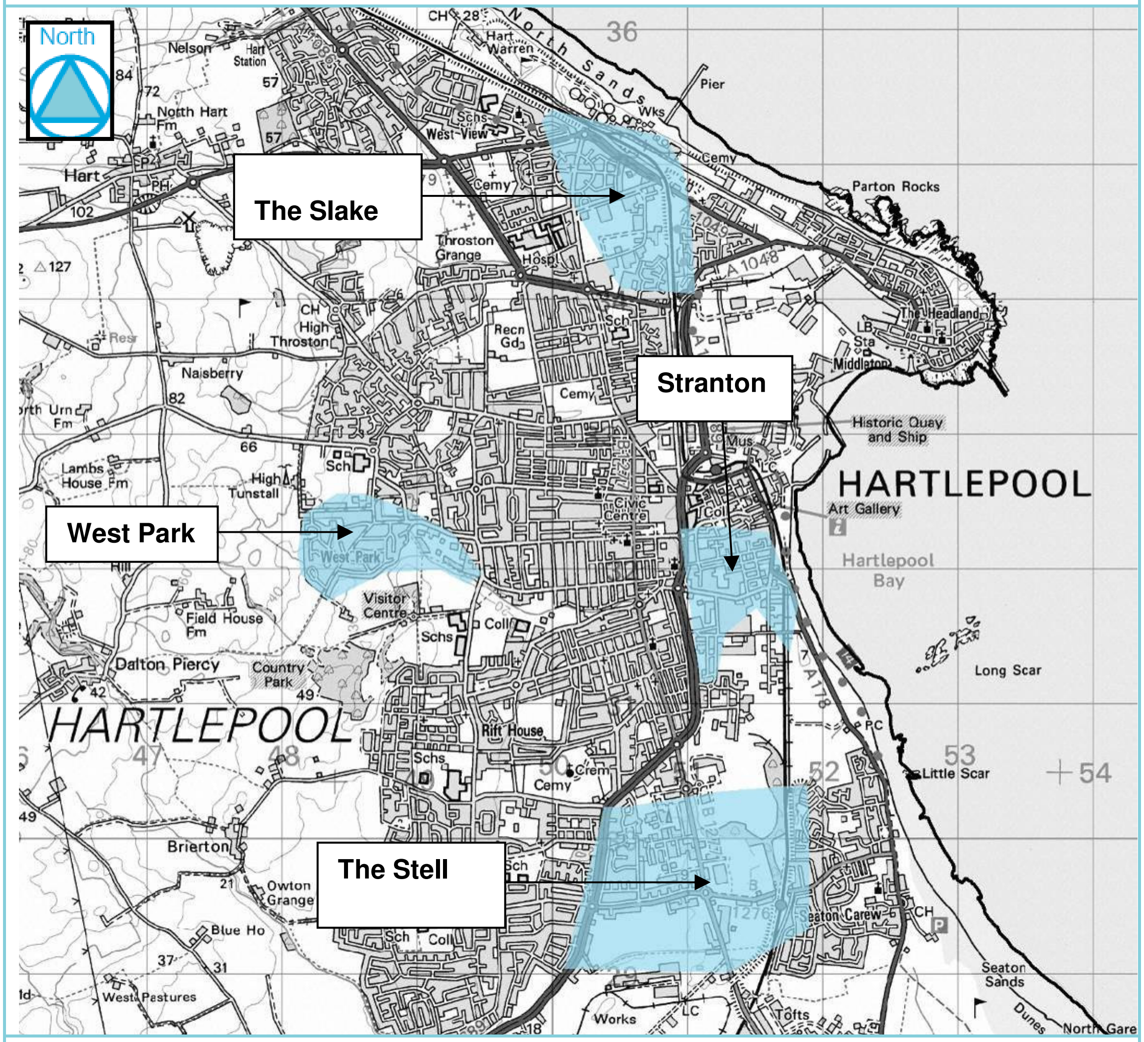
1.3.3 Critical drainage areas

The Level 1 SFRA identified a number of candidate Critical Drainage Areas (cCDAs - see Figure 1-3). CDAs are locations where the drainage system (in an area including combined sewers, surface water sewers and culverted watercourses) causes flooding during heavy rainfall events. These are areas where a strategic drainage solution could be found to resolve and number of interlinked issues. This Level 2 SFRA will look at these areas in more detail and confirm them as Critical Drainage Areas (CDAs) if necessary. The areas to be looked at in more detail are:

- The Slake area
- West Park
- Stranton
- The Stell

The SFRA will cover these areas in addition to any green infrastructure opportunities and surface water flooding areas identified by the more detailed surface water mapping.

Figure 1-3: Candidate Critical Drainage Areas



2. Tidal Flood Risk and Flood Defence Review

2.1 Introduction

This section describes the existing physical environment along the north Tees Estuary within Hartlepool BC round to the open coastline up to Seaton Carew (including a summary of the flood defences).

Figure 1-1 shows the study area and the sites being assessed as potentially at risk of tidal flooding. Information on the open coastline and estuary has come from the Shoreline Management Plan[3] (SMP2), draft Tees Tidal Strategy and through reviewing satellite images and LIDAR data (digital elevation model). This review will assist in developing flood modelling scenarios and understanding tidal flood risk in this area. Chapter 3 describes the modelling scenarios and tidal flood risk.

2.2 Physical Environment

2.2.1 Extreme flood levels

Extreme tide levels for the Tees Estuary, provided in Table 2-1, have been taken from the draft Tees Tidal Flood Risk Management Strategy[4]. These levels (including climate change predictions) are the current Environment Agency recommended levels for assessing tidal flood risk at the Tees Mouth.

Within the estuary, mean high water springs are 2.7m AOD and the highest astronomical tide is 3.3m AOD. The highest recorded water level of 4.0m on the Tees Estuary was a result of a large surge tide (1953 event).

Sea levels on the Tees are forecast to rise by 0.3m over the next fifty years and 0.9m over the next 100 years as a result of sea level rise. Although stormier conditions can be expected in the future, any impact in terms of increased wave heights within the estuary adjacent to the Borough will probably be of little consequence compared with the impact of sea level rise. Figure A1 in Appendix A shows the areas below these extreme tide levels.

Table 2-1: Still water tide levels at Tees Mouth

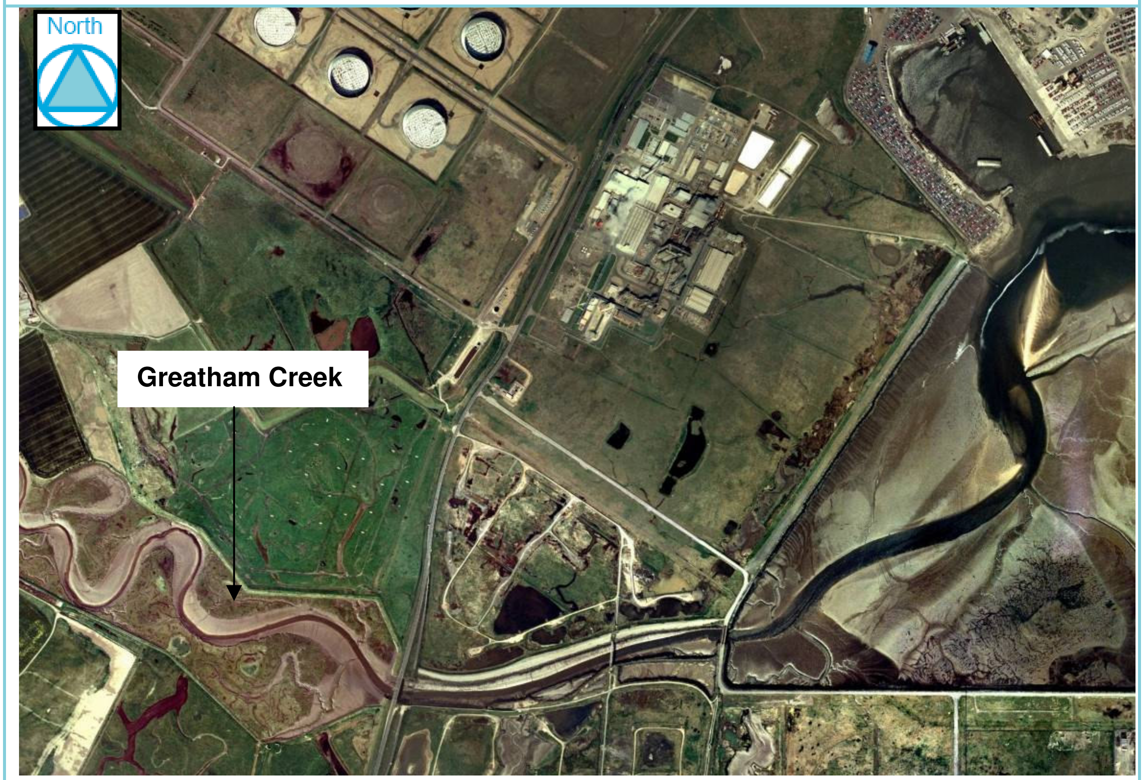
Return Period (years)	Probability (%)	Level by Year (m AOD)				
		2007	2025	2055	2085	2107
1	100.0	3.353	3.398	3.608	3.908	4.238
2.5	40.0	3.488	3.533	3.743	4.043	4.373
5	20.0	3.590	3.635	3.845	4.145	4.475
10	10.0	3.693	3.738	3.948	4.248	4.578
25	4.0	3.843	3.888	4.098	4.398	4.728
50	2.0	3.933	3.978	4.188	4.488	4.818
100	1.0	4.073	4.118	4.328	4.628	4.958
200	0.5	4.186	4.231	4.441	4.741	5.071
300	0.33	4.244	4.289	4.499	4.799	5.129
500	0.2	4.303	4.348	4.558	4.858	5.188
1000	0.1	4.403	4.448	4.658	4.958	5.288
	Shading demonstrates the reduction in return period with time					

[3] Shoreline Management Plan 2, River Tyne to Flamborough Head, North East Coastal Authorities Group, February 2007, Final Report
[4] Environment Agency (2008) Tees Tidal Flood Risk Management Strategy

2.2.2 North Tees Estuary

The Tees Estuary marks the southern boundary of Hartlepool BC. The Hartlepool BC boundary then follows Greatham Creek to the west. The Level 2 SFRA tidal flood risk study area starts at Greatham Creek. Figure 2-1 identifies Greatham Creek to the west as it forms part of the Tees Estuary to the east. The existing Tioxide site and an oil storage depot can be seen at the top of the image.

Figure 2-1: North Tees Estuary in Hartlepool BC



Sections of Greatham Creek are defended some of which have been known to breach in the past. Volume II of the Level 1 SFRA provides some background details on the Greatham Creek defences and breach history (see section 2.2.4). As Greatham Creek opens up into the Tees Estuary, there is a line of raised defences alongside the Tioxide chemical works. This is called the Greenabella Sea Wall.

There is also a NFCDD (see Glossary) defence line in front of the nuclear power station, these represents the generally higher ground of the nuclear power station (not a raised embankment). In addition, there is an outfall at the nuclear power station which is fed by a ditch flowing round the power station. It is likely that this outfall has a tidal gate (to prevent tidal ingress). This should therefore be regarded as a flood defence asset as it prevents tidal water reaching low lying land to the rear of the power station.

Within Hartlepool BC, the assets discussed above are the only formal flood defences on the Tees Estuary (see Figure 2-2 for the flood defence locations). They currently protect the Tioxide chemical works and nuclear power station from tidal flooding; the rest of the defended land is used for grazing. However, behind the Greatham Creek defences and Greenabella Sea Wall, there are some secondary flood defence bunds. These earth bunds are in place to protect the Phillips Petroleum Storage Depot (behind Tioxide) from flooding. The location of the oil storage bunds can be seen in Figure 2-2.

The standard and condition of the above defences is important as both the chemical works and power station are potential development areas where significant expansion is possible in the future.

Although the Greatham Creek defences have breached in the past, reconstruction of these raised defences on the Tees Estuary took place the 1990s. The embankments have been strengthened and raised and there has not been a defence breach since. A summary of the condition and standard of the defences are below:

Greenabella Seawall

This raised flood defence is maintained by the Environment Agency and has a condition assessment rating of 2. This means that the defence is in generally good condition. There may be minor defences but any remedial works would be non urgent.

Works were carried out on the Greenabella Sea Wall in the mid 1990s when the space between the inner and the outer banks was filled. A recent survey indicates that the crest level ranges from 5.16m to 5.32m AOD. This is above all of the extreme tide levels being studied (see Table 2-1).

Where the Greenabella Sea Wall cuts in to the north west (adjacent to Graythorp dock), the defence line represents an area of raised land (around 100m wide) which is used for industrial storage rather than a raised defence embankment. Within the modelling, this section should therefore be considered a permanent topographical feature rather than a raised defence line.

Greatham Creek (east section)

These defences are also owned by the Environment Agency and have a condition rating of 2. The raised embankments are of substantial construction, following works to the embankments in the 1990s. However, the Tees Tidal Strategy states that the embankment is founded on very soft silky clay and they appear to be permeable, which may lead to an increased risk of breach failure.

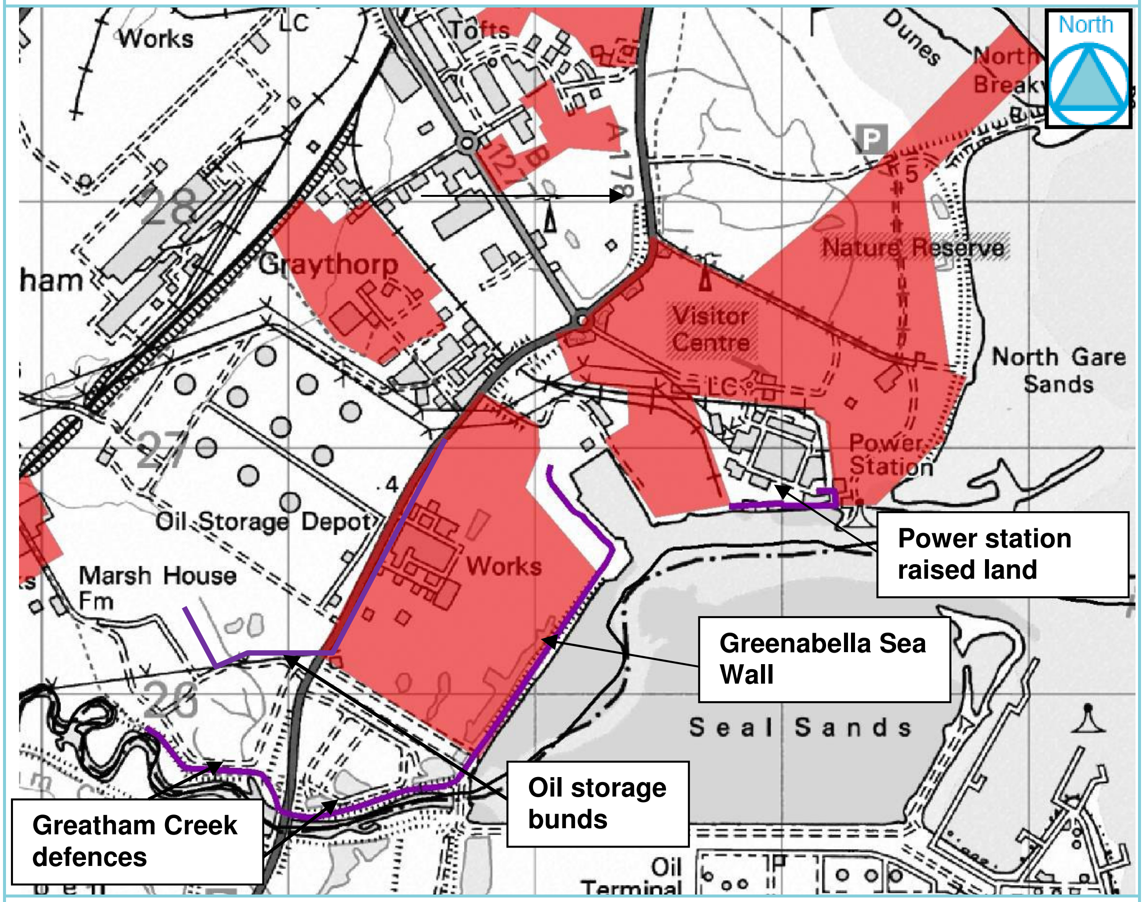
This section of defence was reconstructed in the mid 1990s to a level of 4.6m AOD. A recent survey indicates that the crest level ranges from 4.18 to 4.36m AOD. This is above the present day 1 in 200 year flood level, but may be overtopped and/or breached during the 1 in 1000 year flood level and the 1 in 50 year level with 50 years climate change added.

Greatham Creek (west section)

This defence section is owned by the Environment Agency and has a condition rating of 2. This section of defence was reconstructed in the mid 1990s to a level of 4.6m AOD. A recent survey indicates that the crest level ranges from 4.17 to 4.15m AOD. This section of the defences may be overtopped and/or breached during the present day 1 in 200 year event. However, with 50 years climate change added, the embankment could be overtopped by much lower return period events.

The Tees Tidal Strategy states that due to the condition of the banks and incidents of breaches, a breach in the Greatham Creek defences is more likely than a breach of the Greenabella Sea Wall.

Figure 2-2: Tees Estuary Flood Defences



Future Management

The Tees Tidal Strategy's preferred flood risk management option for this part of the Tees Estuary is to raise the defences east of A178 and re-align the defences to the west of A178 to tie in with the oil storage bunds (see Figure 2-1). This will involve realigning the Greatham Creek embankment along eastern edge of the A178, following the line of emergency access track and tie in with the Greenabella Seawall. Realigning the defence to western edge of the A178 will tie in with oil storage bunds. This option would also include the creation of a new inter-tidal habitat adjacent to Greatham Creek (but remote from the proposed development areas).

The Tees Tidal Strategy recommends that the defences are built and maintained to a 1 in 25 year standard of protection (with the effects of climate change added). If this option was taken forward then the existing and proposed development would be protected up to this design event into the future.

The SMP2 includes lines showing how the shoreline may change over the next 100 years, based on coastal process including erosion rates. This shows that the north Tees Estuary shoreline may retreat but only by tens of meters over the next 100 years. This would have little impact on the existing and proposed development, especially as the Tees Tidal Strategy (which comes above the SMP2) aims to maintain the defences on this part of the estuary.

2.2.3 Coastline to Seaton Carew

Moving north from the Tees Estuary, the tidal flood risk study area extends round the estuary mouth from the North Gare breakwater, up to Seaton Carew. Along this line of the coast there is a dune system and NFCDD shows some raised defences leading up to and through Seaton Carew.

The dune system is well vegetated and comprises a series of ridges further back indicating the line of the former mouth of the Tees and the accumulation of sediment that has occurred following the construction of the North Gare breakwater (1890s) and the training of the estuary mouth. Figure 2-3 shows part of this coastline and the low lying land to the west of the Seaton Sands dunes.

Figure 2-3: Dune System at Seaton Sands

Before the North Gare Breakwater, there is a relatively narrow, straight section of the dunes overlying a raised slag bank (which was constructed at the same time as the breakwater) which is called North Gare Sands. This line of dunes ranges in width between 20m and 80m and between 7 and 9m AOD high. This is above all of the extreme tidal levels (including the effects of climate change) and would therefore prevent tidal inundation to the lower land behind the dunes.

To the north of the breakwater the dunes system, called Seaton Sands, is much wider. This dune system comprises two main ridges with a lower section at around 3.5m AOD in the middle. The main dune ridge ranges in height between 6 and 8m AOD, which again is above all of the extreme tide levels being considered for this study (5.07m AOD).

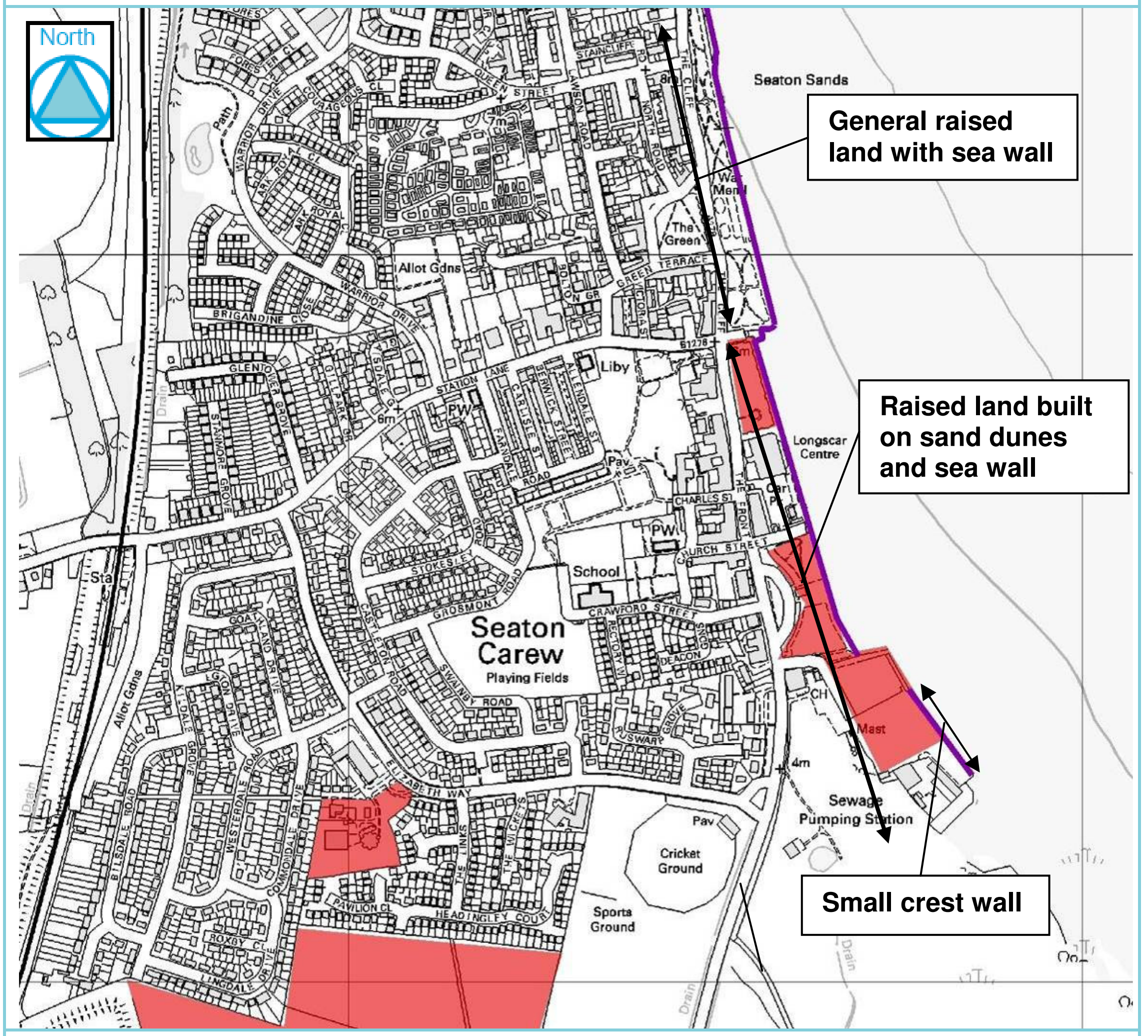
To the back of the dunes is a wide, flat and low expanse of estuarine land which is well vegetated and lies at around 2m AOD. To the rear of this area lies the core industrial land of the northern Tees Valley. The lower parts of this industrial land are at between 3 and 4m AOD. The dunes provide the primary flood defence line along the coast, with the north Tees Estuary flood defence embankment preventing flooding from the Tees Estuary.

The study area ends at Seaton Carew (at the Seaton Sands development site) which is shown to be defended in NFCDD. In fact, this defended area represents how Seaton Carew has been built upon the dunes which extend from the south. This produces an area of raised land which ties in with the promenade and sea wall at the coastline (i.e. the town is at the same height as the sea wall). This raised part of Seaton Carew (built on sand dunes) is between 5 and 5.5m AOD and is between 40 and 100m wide. A lower part of the town (lying at around 4.5m AOD) is behind the raised area, but this is not very wide and quickly increases in height to the west. This topography stretches up to Station Lane (B1276) where Seaton Carew is built on higher ground.

The main part of the town sea front is set back and the sea wall is fronted by a relatively wide, typically dry sand beach. The SMP2 states that while still exposed under more severe storm conditions, the sea wall is given considerable protection by the beach.

However, there is one raised defence section at the south part of Seaton Carew. This is a small crest wall set at around 4.7m AOD and is approximately 150m long. At this height, the defence would be overtopped during the 1 in 200 year climate change flood event (with 100 years sea level rise added). With the small wall removed, the development site would flood at the 1 in 1000 year event. Figure 2-4 shows the location of the coastal defences at Seaton Carew.

Figure 2-4: Tees Estuary Flood Defences



Future Management

The SMP2 policy for this stretch of coastline is to 'hold the line'. This means that the sea wall at Seaton Carew and the North Gare breakwater will be maintained and improved to take account of climate change so that erosion and flood risk does not increase in the future (this includes the Seaton Sands development site). The first step in this process is to produce a coastal strategy. A coastal strategy for Seaton Carew is currently being undertaken, this should eventually lead to a flood defence improvement scheme in line with the SMP2 management policy. The SMP2 policy and the initial findings of the strategy confirm that works to reduce the future risk of flooding at Seaton Carew are likely to be undertaken. This means that in the long term, coastal flood risk to existing and proposed development in this area should be sustainable. The SMP2 projected coastline for Seaton Carew (including the Seaton Sands SHLAA site) is predicted to stay as it is over the next 100 years.

However, the SMP2 policy would allow for a retreat of the dune system to the south of Seaton Carew. For Seaton Sands, the SMP2 has provided an estimated erosion rate of 0.4m/year. The lines showing the predicted change in shoreline in the SMP2 illustrates that the dunes may retreat by around 60m over the next 100 years. This is not significant enough to erode any existing or proposed development sites to the south of the dunes (apart from a small section of the proposed new nuclear power station area - this should be looked at in more detail within the FRA of the new nuclear power station). However, over 100 years, the narrow parts of the North Gare dune system may erode back leaving the low lying undeveloped and industrial land exposed to flooding from the open coast.

2.3 Flood Zone and Projected Levels Comparison

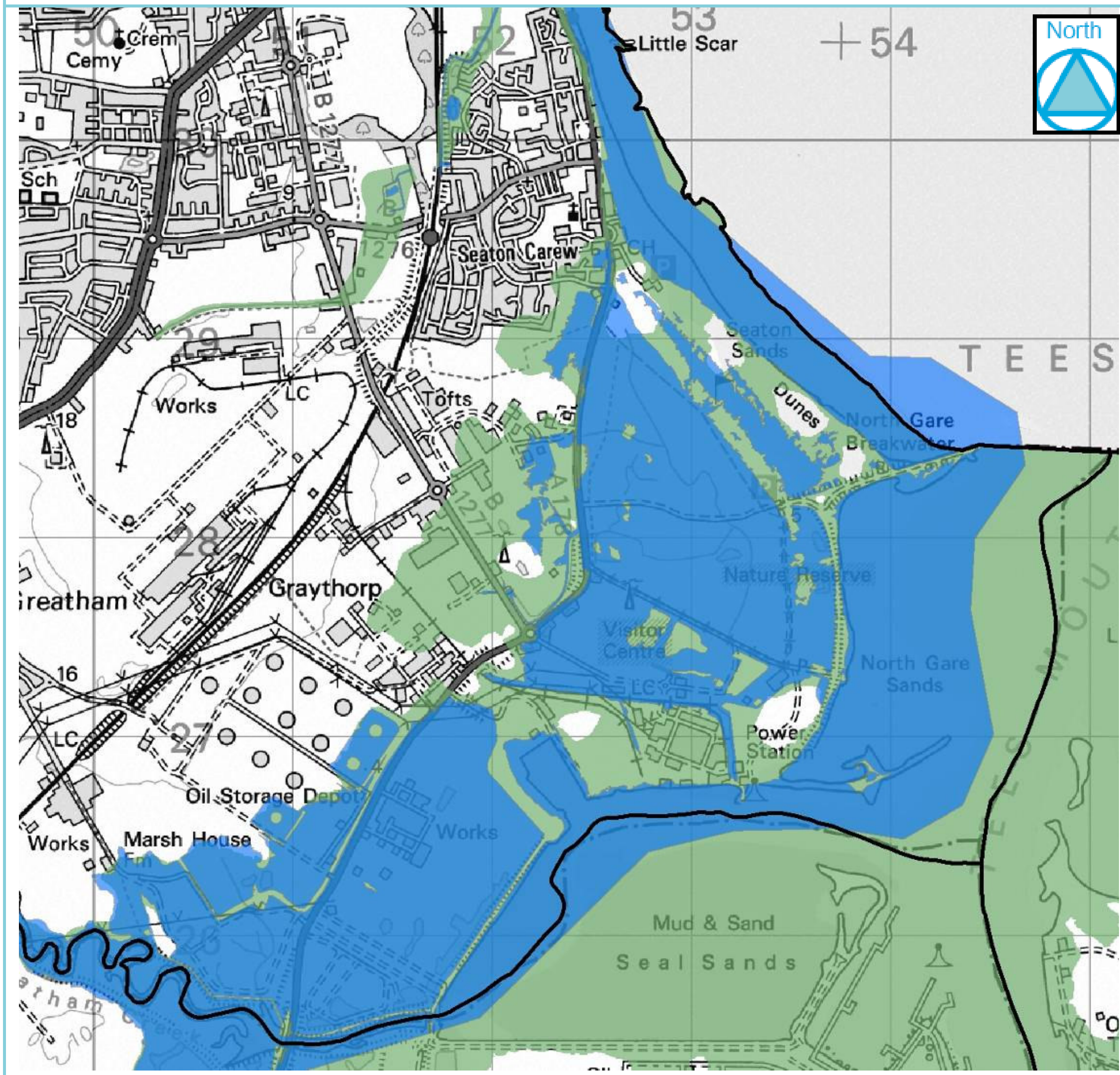
A Level 2 assessment is being undertaken for the tidal flood risk area primarily to assess the risk of flooding to the proposed development sites in this area. New modelling is being undertaken as a draft tidal model output (completed for the Level 1 SFRA) indicates that the current Flood Zone maps overestimate the tidal flood extent in this area. This can be expected in some locations as the modelling was completed some time ago and used flood levels that have been superseded and a broad scale topographic model. New extreme flood levels (see Table 2-1) and LIDAR (more accurate topographic data) is now available.

Even before modelling has taken place, the difference in the current Flood Zones and the flood levels can be seen. Figure 2-5 shows a comparison of the current Flood Zone 3 and the latest 1 in 200 year flood level (equivalent of Flood Zone 3) projected onto the most up to date elevation data (LIDAR).

The current Flood Zone 3 (green) shows a significant part of the industrial area next to the Tees Estuary to be at risk of flooding (including Tioxide and the nuclear power station). The undeveloped area behind the Seaton Sand and parts of Graythorp and Tofts are also within Flood Zone 3. The latest 1 in 200 year flood level projected onto the latest DTM (blue) shows that the nuclear power station and land leading towards Graythorp Dock is not at risk. The Graythorp and Tofts Farm employment area is also shown to be free from flooding during this event. The flood extent from the coastline into Seaton Carew is also between 20 and 100m less than Flood Zone 3.

It should be noted that the blue 1 in 200 year flood level has been projected over topographic data and it does not take into account any natural or manmade barriers to tidal flooding (this would show a further reduction in flood extent). The existing risk and undefended scenarios described in the next chapter use an advanced modelling technique which takes into account barriers to flooding, flow routes and the tidal flood curve.

Figure 2-5: 1 in 200 year level elevation and Flood Zone 3 comparison



Legend

(blue)	4.19m contour 1 in 200 yr level
(green)	Floodzone 3a

3. Level 2 Assessment of the Sites at Tidal Flood Risk

This section focuses on the potential future development sites that are thought to be at risk of tidal flooding (see Figure 1-1). New tidal modelling has been undertaken so that a revised estimate of undefended flood risk (equivalent to the Environment Agency Flood Maps) could be produced. In addition, an estimation of 'existing risk' has been undertaken. The existing risk modelling scenario includes all the manmade and natural barriers to flooding (e.g. raised defences and sand dunes).

From the undefended modelling outputs, it should be possible to conclude which sites are appropriate for development (according to PPS25). For those sites where there is a risk of flooding, the 'existing risk' scenario should provide the evidence to decide whether the sites will be safe once developed, if mitigation measures will be required or in fact if the risk of flooding is too high and the site should be removed during the Sequential Test.

Table 3-4 at the end of this chapter summaries the undefended risk, existing flood risk and the future flood risk requirements for the sites to be taken forward.

Once reviewed by the Environment Agency, the new, undefended flood extents may be integrated into their Flood Zone maps. However, until this is confirmed, the current Flood Zone maps should be used. The 'existing risk' maps can be used to view the actual risk at a strategic level, however, these are different from the Flood Zone maps as they include flood defences.

3.1 Tidal Modelling

A 2D tidal TUFLOW model (see glossary) has been constructed for the north Tees Estuary within Hartlepool BC and follows the coastline leading up to Seaton Carew. A 2D model, models flood flow pathways driven by a tidal curve as opposed to projecting a level over a topographic surface (as was used in the current Flood Zones). This is more realistic and takes into account barriers to flooding and the volume of flood water available to fill the areas at risk.

This modelling has been undertaken in order to estimate flood extents, depths and flood hazard to proposed future developments in Hartlepool BC.

Two modelling scenarios have been developed, 'undefended' and 'existing risk'.

- The existing risk scenario reflects what would happen if a flood event occurred with all the existing flood defences in place.
- The undefended scenario models what would happen if all of the flood defences were removed. This may also include natural defences to flooding e.g. sand dunes. However, a distinction is made between a permanent topographic feature and a natural barrier that could change and/or breach in the future.

Section 2.1.2 and 2.1.3 provides a description of the raised defences and the natural barriers to flooding. The modelling scenarios and the results are described in sections 3.2 and 3.3 below. A summary has been provided in Table 3-1.

Table 3-1: Tidal Modelling Scenarios

Scenario	Description	Outputs	Return periods
Existing Risk	All raised flood defences and sand dunes in place.	Flood extents, hazard and depth	1 in 200, 1 in 1000 and 1 in 200 + 100 years seal level rise
Undefended	Raised defences on the Tees Estuary and the section of dunes at North Gare Sands removed. Tidal gate at the nuclear power station removed. Wider dunes at Seaton Sands kept. Raised coastal frontage not lowered at Seaton Carew but small crest wall has been lowered.	Flood extents, hazard and depth	1 in 200, 1 in 1000 and 1 in 200 + 100 years seal level rise

3.2 Undefended Modelling Scenario

This tidal modelling scenario was produced to identify the level of flood risk in the study area if all of the manmade and natural defences were removed. This is equivalent to the Environment Agency's Flood Zones, which are also illustrates undefended flood extents. Details on the defences referred to in this introduction can be found in sections 2.1.2 and 2.1.3.

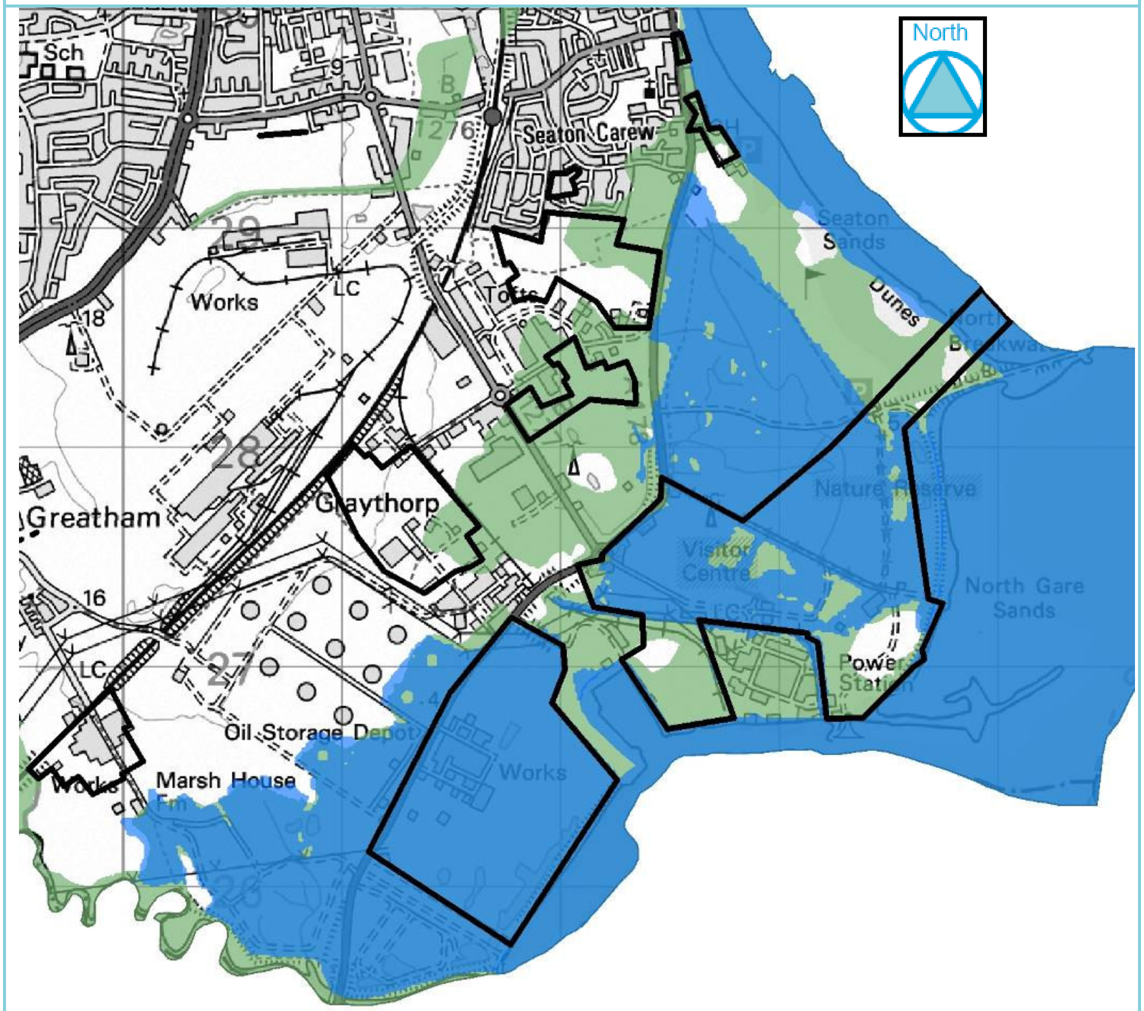
Starting with the Tees Estuary, the raised embankments on Greatham Creek and the Greenabella Sea Wall were removed. The raised land at Graythorp Dock was not lowered as this has been judged wide enough to be considered a permanent topographical feature. In addition, the NFCDD defence line at the nuclear power station represents an area of raised ground which the power station is built on. This has not been lowered as this area is now permanently raised. However, the presumed tidal gate has been removed on the power station outfall to allow tidal flood water to flow around the back of the power station, via a ditch and inundate the lower land behind.

Before the North Gare breakwater at North Gare Sands, there is an area of sand dunes that are relatively narrow and potentially prone to erosion (see section 2.1.3). Due to the apparent vulnerability of this section of dunes, they have been lowered to the elevation of the surrounding land for the undefended scenario. However, the much larger and wider expanse of sand dunes at Seaton Sands has been left in. This is because they are wider and less vulnerable to erosion and breaching. This has been confirmed when reviewing the SMP2 (see 'future management' in 2.1.3)

3.2.1 Current Flood Zone and Undefended Scenario Comparison

Figure 3-1 shows a comparison of the current Flood Zone 3 and the undefended 1 in 200 year flood extent (equivalent to Flood Zone 3). This shows that the current nuclear power station area (not the extension), Century Park, Graythorp, Tofts Farm, Tees Road Seaton and Seaton Sands (see Figure 1-1 for their location) are not at risk from the 1 in 200 year undefended flood event, whereas they are shown to be within Flood Zone 3. If this newly produced 1 in 200 year flood extent is adopted by the Environment Agency, then it should show that these sites are not in Flood Zone 3. However, the Tioxide and nuclear power station development areas are at risk from the undefended 1 in 200 year flood event so would remain in Flood Zone 3.

Figure 3-1: Comparison of Flood Zone 3 and undefended 1 in 200 year extent

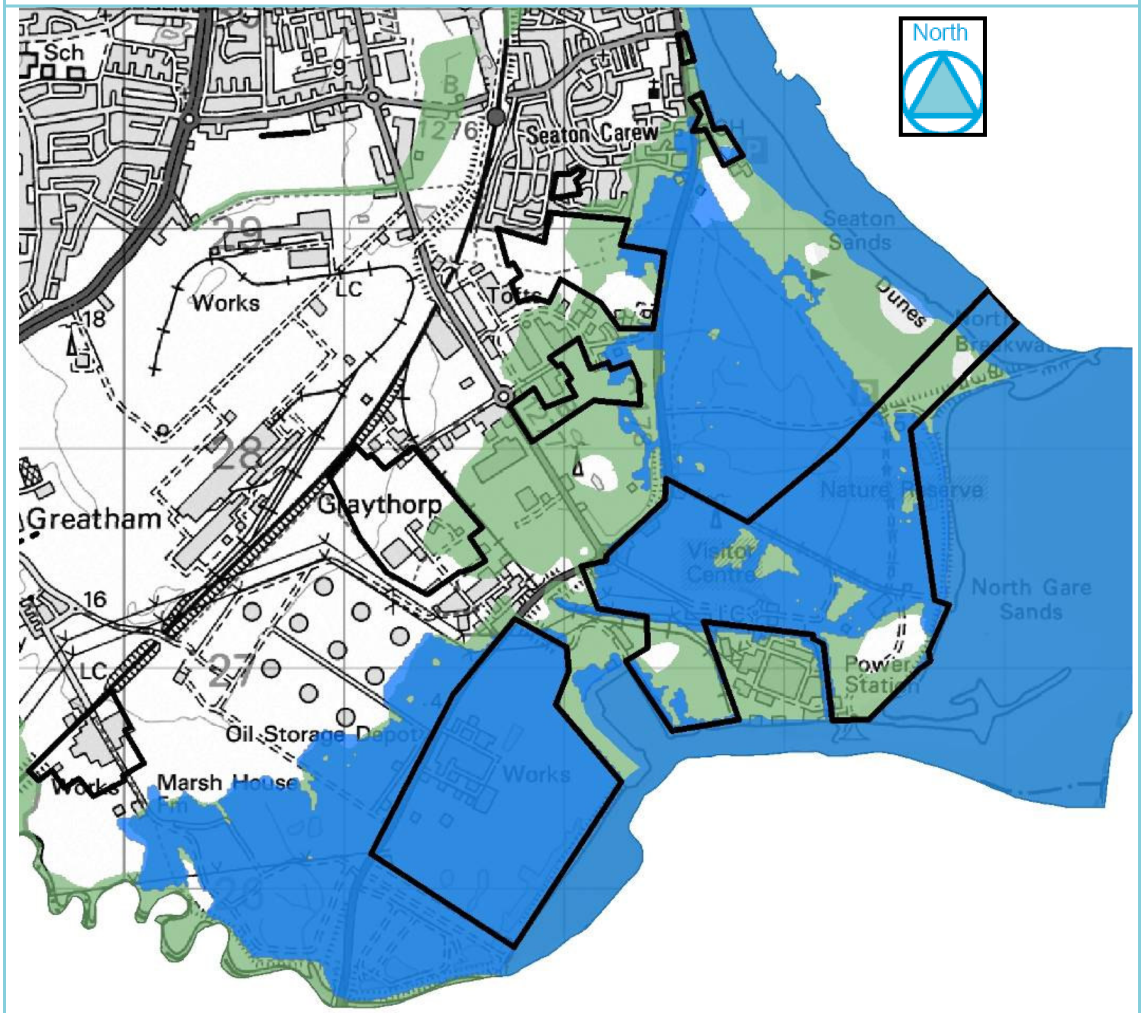


(blue)	1 in 200 year undefended flood extent
(green)	Flood Zone 3

Figure 3-2 is similar to Figure 3-1 but compares the current Flood Zone 2 with the 1 in 1000 year flood extent (equivalent to Flood Zone 2). This shows that Century Park and Graythorp are not at risk while only very small parts of Tofts Farm and Tees Road Seaton are at risk. As these sites are not shown to be at risk (or only a small part where the site boundary can be easily moved) from the 1 in 200 or 1 in 1000 year tidal flood events, it is recommended that these sites can be taken forward for development (subject to an FRA) and do not need be studied in any more detail during this Level 2 SFRA. However, Figure 3-3 shows that Tofts Farm and Tees Road Seaton are at risk from the 1 in 200 year plus CC flood extent. This event takes into account the predicted increase in sea level as a result of climate change (over the next 100 years). Although not at risk now, these could be at risk in the future if the natural protection of the North Gare dunes is removed. Hartlepool BC may therefore want to take this into account for future development proposals.

The Tioxide site, nuclear power station development areas and Seaton Sands development site are shown to be at risk from the 1 in 1000 year event. The remainder of the study will therefore focus on these sites.

Figure 3-2: Comparison of Flood Zone 2 and undefended 1 in 1000 year extent

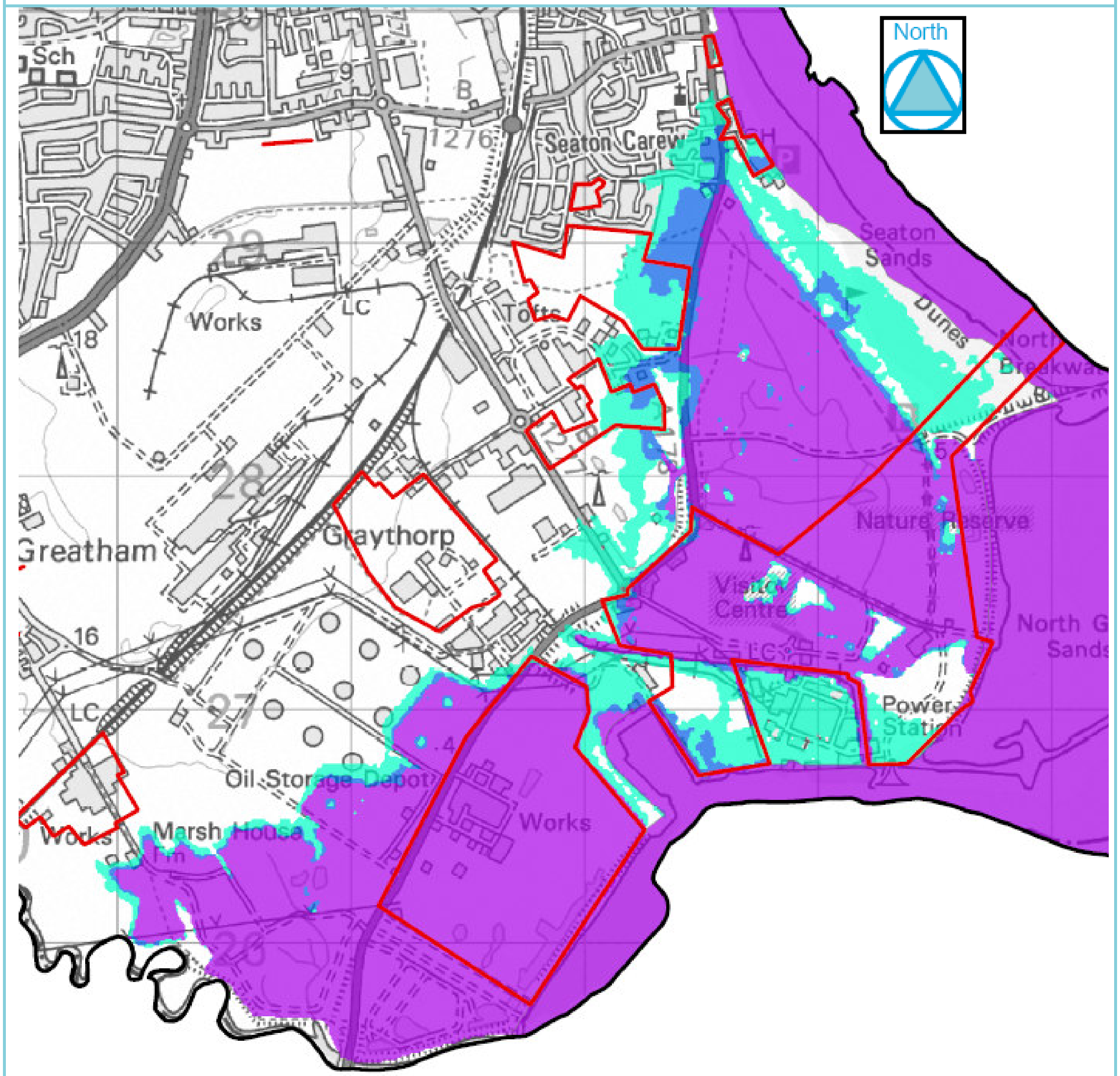


(blue)	1 in 1000 year undefended flood extent
(green)	Flood Zone 2

3.2.2 Flood extents and pathways

Figure 3-3 shows the 1 in 200, 1 in 1000 and 1 in 200 year plus CC (with 100 years of sea level rise added) undefended flood extents (full A3 size figures can be found in Appendix A, Figure A7). The main inundation areas are via the lowered Greenabella Sea Wall and the lowered North Gare dunes. This emphasises the importance of these manmade and natural flood defences. The current nuclear power station would be inundated during the 1 in 200 year plus CC event not because defences have been removed, but because of the general elevation of the site. This should be taken into account if the proposed new power station goes ahead.

Figure 3-3: Flood extents for the undefended scenario at the Level 2 SFRA sites



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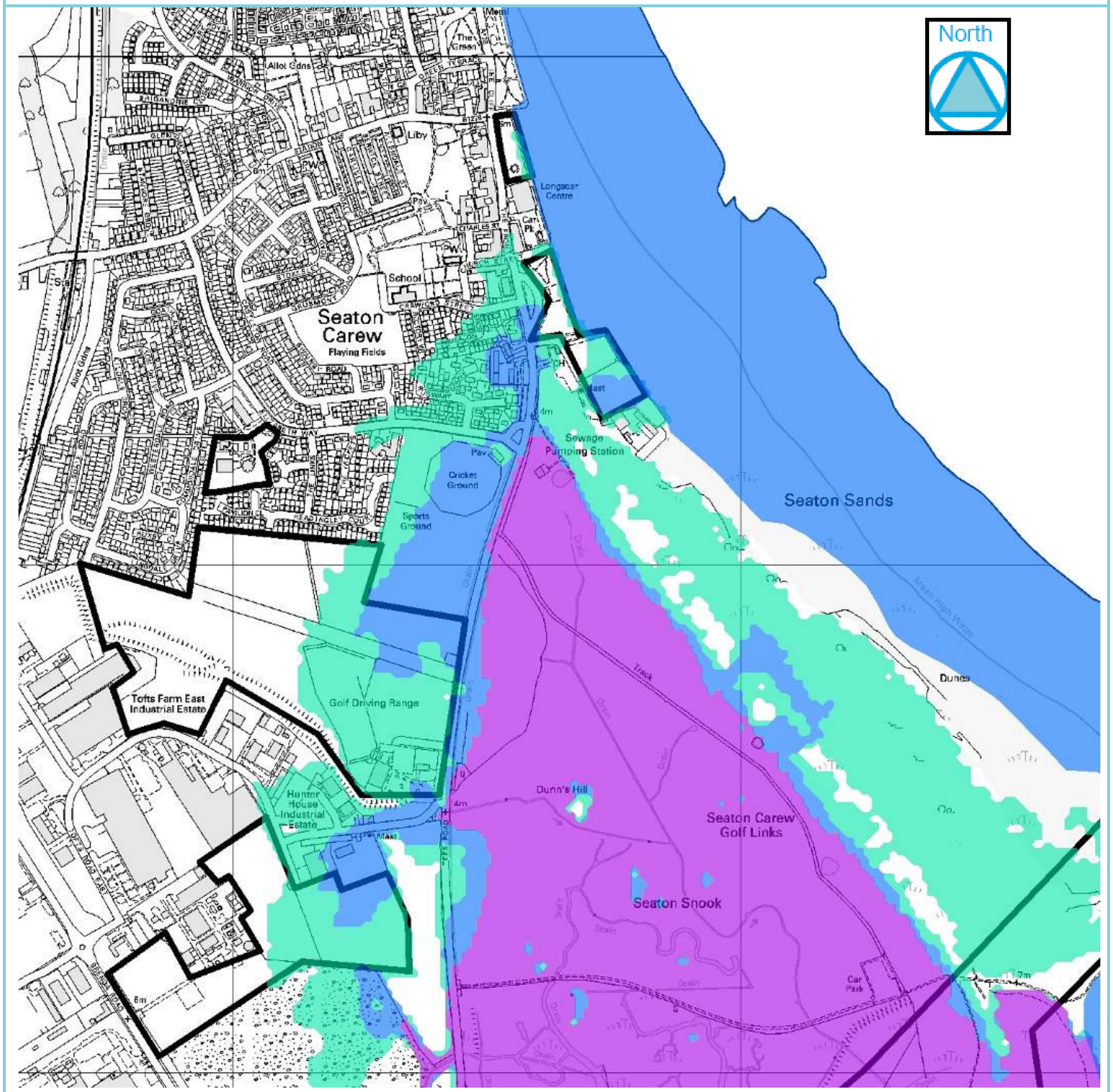
- Allocations
- 1 in 200 year level (4.19 mAOD)
- 1 in 1000 year level (4.40 mAOD)
- 1 in 200 year plus climate change level (5.07 mAOD)

At Seaton Carew, the town frontage is generally high enough to be free from tidal flood risk (due to being originally built on the dune system). However, with the low crest wall removed at Seaton Sands, the south part of this development site is inundated at the 1 in 1000 year event (see Figure 3-4). This SHLAA site is therefore reliant on the raised flood wall for the 1 in 1000 year event but would not flood at the 1 in 200 year event even if this wall were removed. The 1 in 200 year plus CC flood event would flood a larger part of the Seaton Sands site and inundate the low lying area of Seaton Carew to the west (behind the raised part of Seaton Carew - see Figure 3-4).

Figure 3-4: Flood extents for the undefended scenario at Seaton Carew



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- Allocations
- 1 in 200 year level (4.19 mAOD)
- 1 in 1000 year level (4.40 mAOD)
- 1 in 200 year plus climate change level (5.07 mAOD)

3.2.3 Flood depth

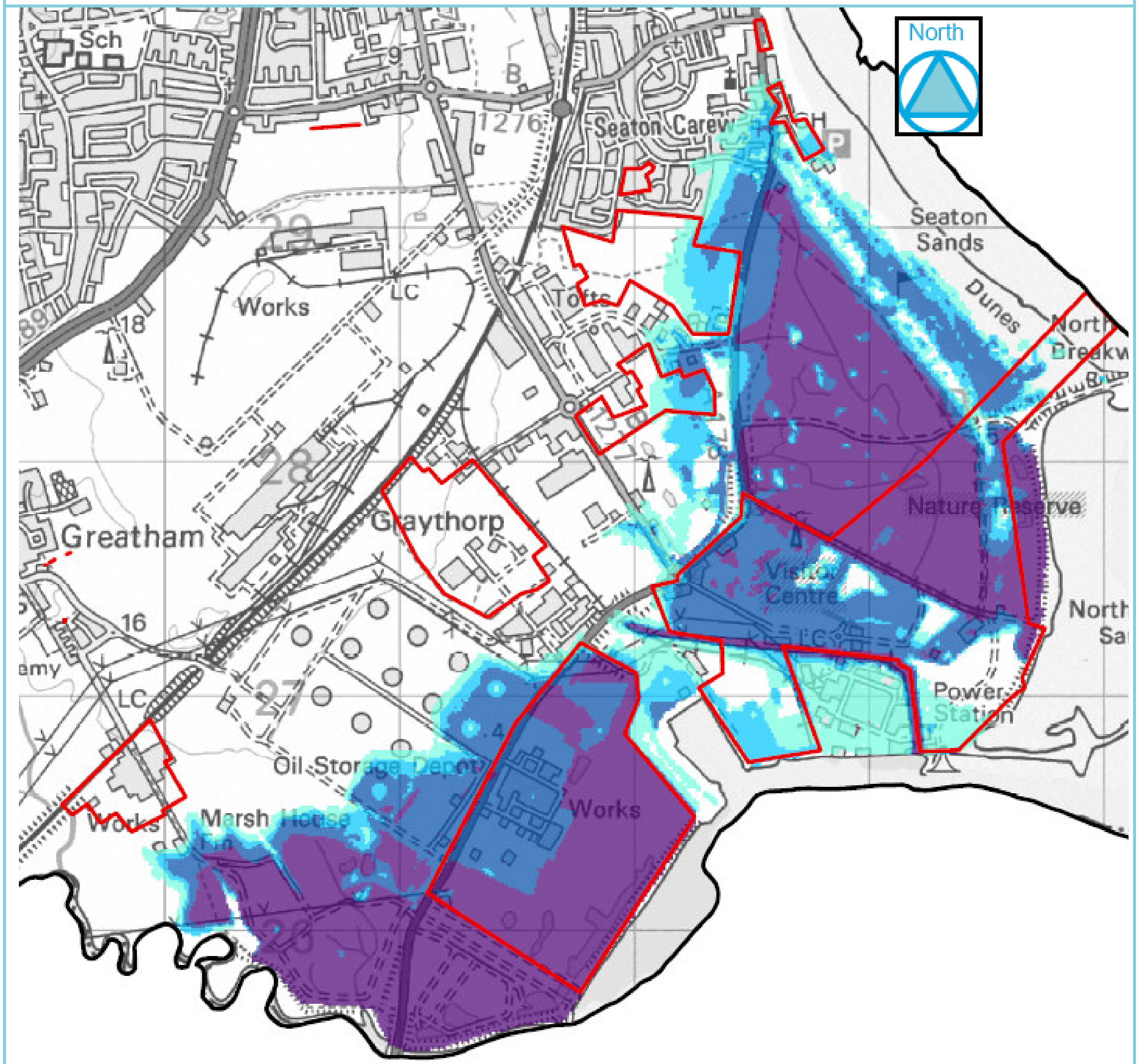
The section describes the undefended flood depth results for the 1 in 200 plus CC event. This severe event has been described as it is specified by the Environment Agency that the 1 in 200 year event with climate change should be taken into account for proposed developments.

The undefended flood depth for the 1 in 200 year plus CC event can be seen in Figure 3-5 below. A3 size flood depth figures for the three return periods modelled can be seen in Appendix A, Figures A8 to A10.

If the Greenabella Sea Wall were removed, the Tioxide land would flood to depths greater than the nuclear power station site. This is because the Tioxide area is on low lying land (at around 1 to 1.5m AOD). The current nuclear power station has been developed on raised land, so this floods to shallow depths. However, the proposed new power station floods to levels similar to the Tioxide site, again due to the site being on low lying land.

The sections of Tees Road Seaton and Graythorp that are flooded at the 1 in 200 plus CC event could flood to depths of up to 1m. For this to occur, the North Gare dunes would need to be breached. The Seaton Sands development site floods to around 0.5m for the 1 in 200 year plus CC event, due to overtopping of the sea wall here.

Figure 3-5: 1 in 200 year plus CC flood depth for the undefended scenario at the Level 2 SFRA sites



0 - 0.5

0.5 - 1

1 - 2

greater than 2

Flood hazard

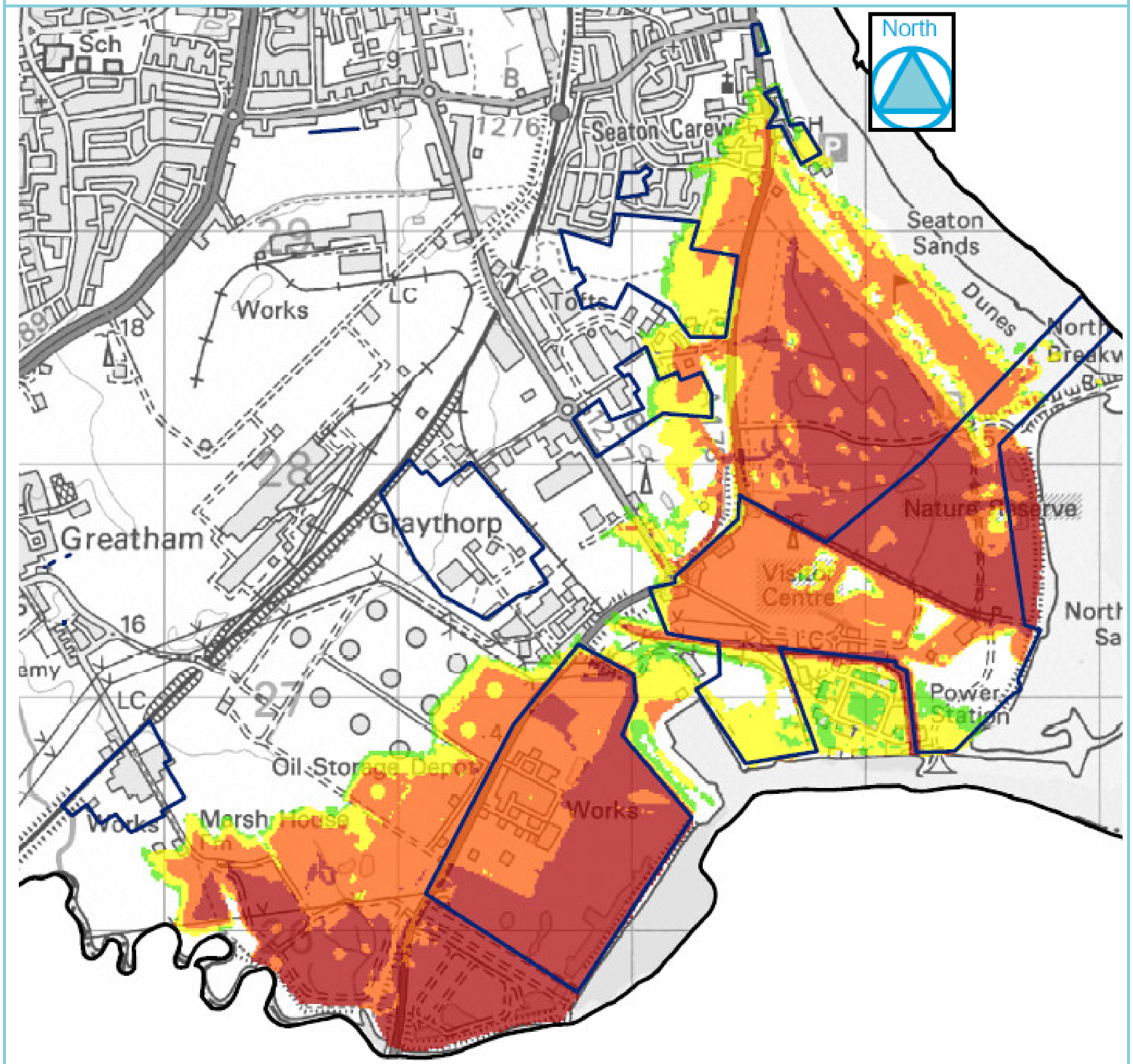
Table 3-2 below (taken from Volume I of Hartlepool BC's Level 1 SFRA) shows the flood hazard thresholds and aligns with the colours in Figure 3-6 and Figures A5, A6, A11, A12 and A13 in Appendix A.

Table 3-2: Flood hazard thresholds		
Flood Hazard d(v+0.5)+DF	Description	Alternative Name / Hazard Class
0	Safe (dry)	None
0 to 0.75	Caution	Low
0.75 to 1.5	Dangerous for some	Moderate
1.5 to 2.5	Dangerous for most	Significant
Over 2.5	Dangerous for all	Extreme

Figure 3-6 shows the undefended flood hazard for the 1 in 200 year plus CC event. For the same reasons described in the undefended flood depth section, the Tioxide and nuclear power station development areas are classed as having between a significant and extreme flood hazard if the Tees Estuary raised defences were removed. The Graythorp and Tees Road Seaton sites would be subject to a moderate flood hazard if the North Gare sand dunes were breached. The Seaton Sands development site would be subject to a moderate flood hazard during the 1 in 200 plus CC event if the low flood defence were removed.

None of the above hazard results take into account a breach in the flood defences. Mitigation measures (see section 3.3) are likely to involve a combination of land raising, flood resilience and some reliance on the raised flood defences. If raised defences are proposed for a future development, a flood defence breach assessment should be undertaken within the Flood Risk Assessment (FRA).

Figure 3-6: 1 in 200 year plus CC flood hazard for the undefended scenario at the Level 2 SFRA sites



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- Caution
- Danger to Some People
- Danger to Most People
- Danger to All People

3.2.4 Summary

The undefended modelling results have shown that with the natural and manmade defences removed, the Tioxide area, proposed new nuclear power station, Tofts Farm, Tees Road Seaton and Seaton Sands sites are at some risk of flooding. During the 1 in 200 plus CC event, the flood depths and hazards will be greatest for the Tioxide and nuclear power station development areas. Graythorp, Tees Road Seaton and Tofts Farm are at risk from lower flood depths and hazards.

Although these sites are shown to be at risk of flooding with the defences removed (some at significant depths), this does not necessarily mean that they cannot be developed. The Exception Test does not apply to any of the sites as the only sites at risk from the undefended 1 in 200 year event (equivalent to Flood Zone 3) are allocated from employment use. However, this next section considers the existing risk and whether all types of developments will be safe as a result of the current flood defence infrastructure and any potential mitigation measures associated with new development.

3.3 Existing risk modelling scenario

This modelling scenario attempts to represent the risk of tidal flooding with all the existing flood defence infrastructure and natural barriers to flooding in place. This therefore includes the Greatham Creek and Greenabella Sea Wall flood defences. The North Gare sand dunes have also been kept within the model as has the small crest wall at the Seaton Sands development site.

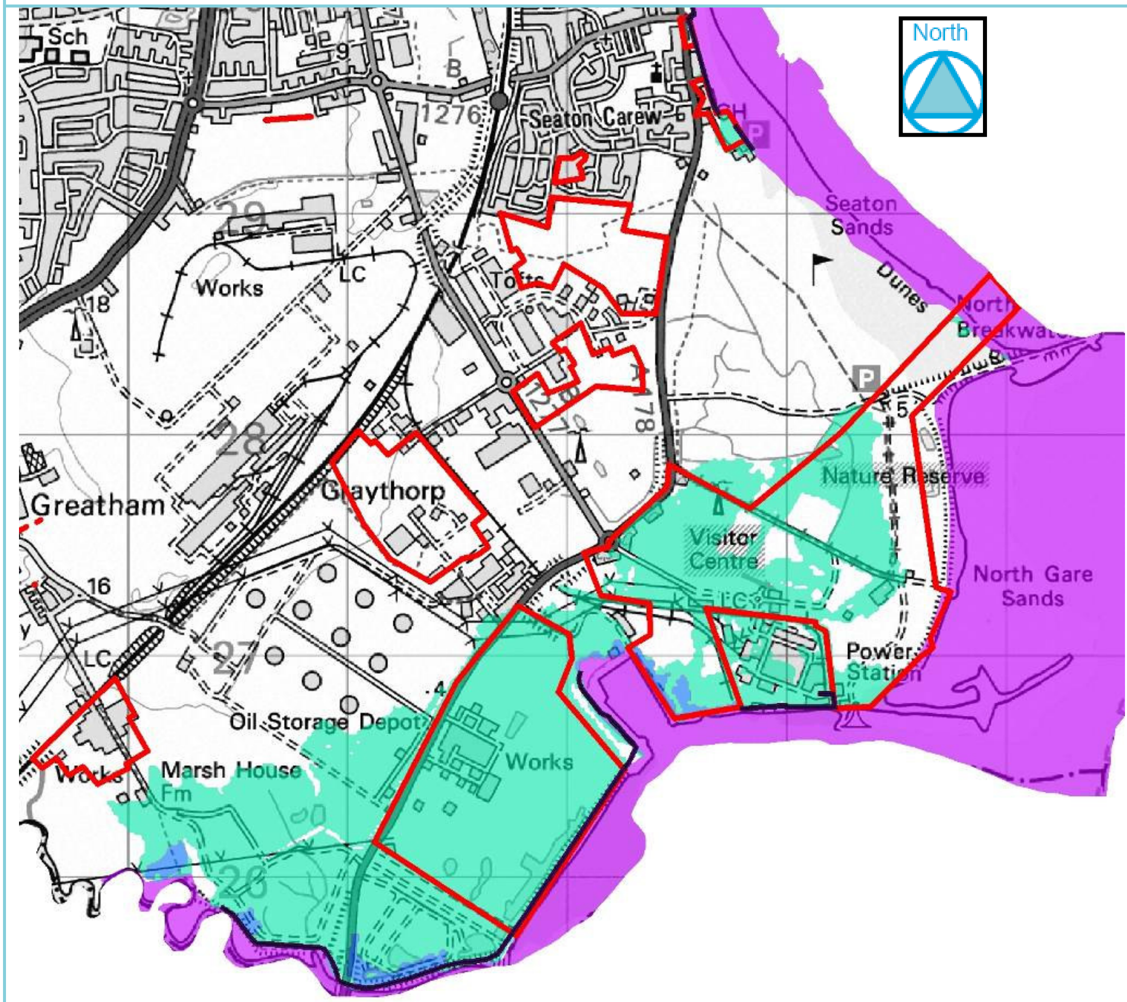
3.3.1 Flood extents and pathways

Figure 3-7, Figure 3-8 and Figure A2 in Appendix A show the 'existing risk' tidal flood extents (Figure 3-7 also shows the location of the raised flood defences). As can be seen in Figure 3-7, with the existing defences and sand dunes in place, the sites are only flooded during the 1 in 200 plus CC event. Of the sites being assessed only the Tioxide development area, proposed new nuclear power station area and Seaton Sands development sites are shown to be at risk from this event.

Up to this event, the Greatham Creek defences prevent overtopping (apart from some minor overtopping at the 1 in 1000 year event). The Greenabella Sea Wall and the general raised ground adjacent to the power station prevent inundation before the climate change event. At the 1 in 200 plus CC event, the Greatham Creek defences are outflanked at Marsh House Farm and overtopped. The Greenabella Sea Wall is also overtopped and this flood event is great enough to form a flood pathway across the existing nuclear power station and into the lower land to the north (proposed nuclear power station area).

This shows that the Tioxide and nuclear power station sites are not at as great a risk as shown by the current Flood Zones and the undefended flood extents. However, the risk from the climate change event and the long term condition of the flood defences should be taken into account before development can be allocated. This is discussed in the next sections.

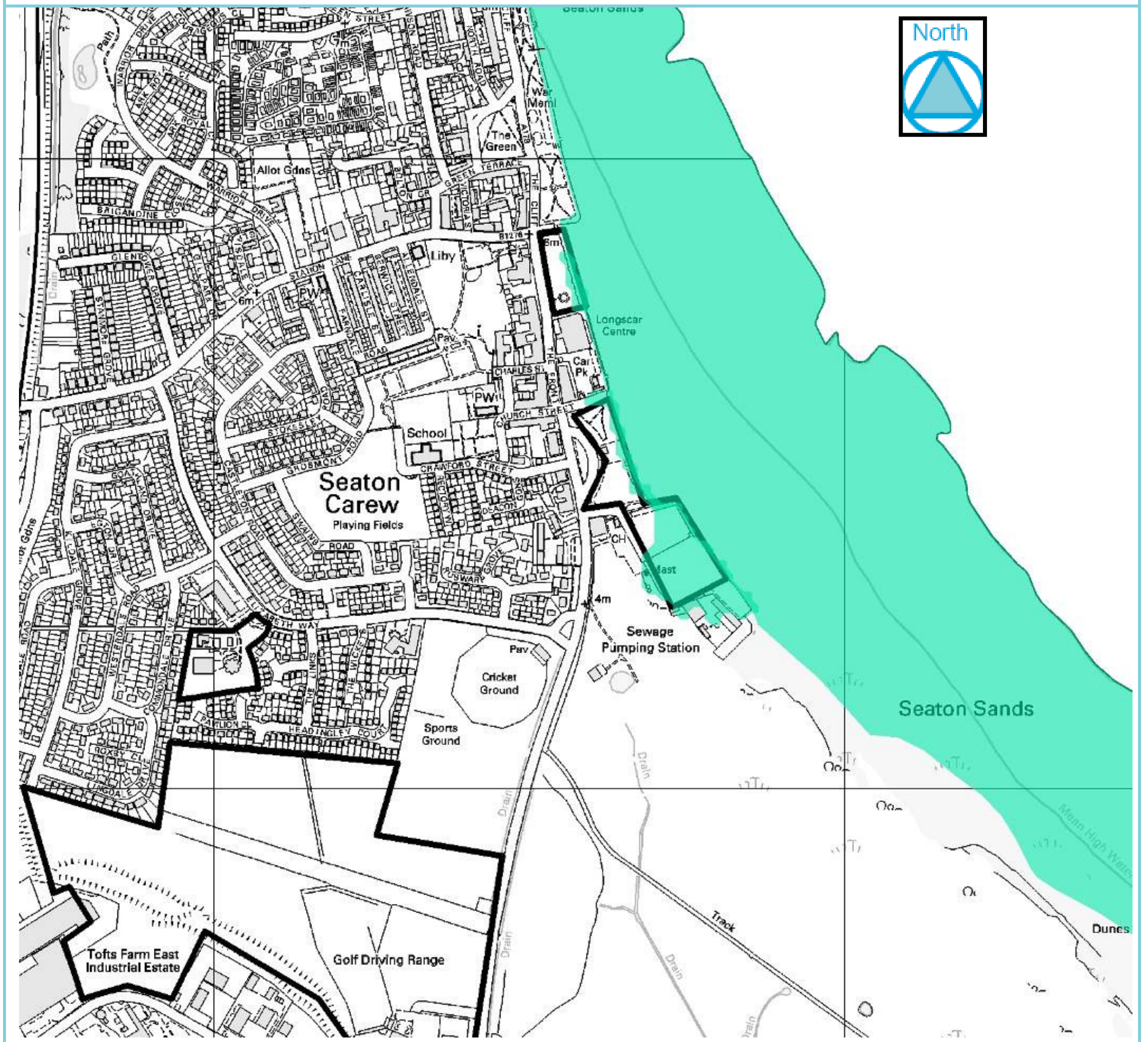
Figure 3-7: Flood extents for the existing risk scenario at the Level 2 SFRA sites



- Allocations
- 1 in 200 year level (4.19 mAOD)
- 1 in 1000 year level (4.40 mAOD)
- 1 in 200 year plus climate change level (5.07 mAOD)
- Hartlepool Borough Council

Figure 3-8 below shows the existing risk to the Seaton Sands SHLAA site. For the existing risk scenario, this site is only flooded at the 1 in 200 plus CC event. At this flood event, the flood wall is overtopped.

Figure 3-8: Flood extents for the existing risk scenario at the Level 2 SFRA sites



1 in 200 year plus climate change

3.3.2 Flood depth and emergency access

New development should be flood free during the 1 in 200 year event, flood risk mitigation measures should also take into account climate change (i.e. added to freeboard). New development should be able to manage the risk from the 1 in 1000 year event (or the 1 in 200 yr plus CC event, whichever is higher). This does not necessarily mean that the development should be flood free for the 1 in 1000 year event, but measures such as flood resilience (see glossary) should be in place up to this event.

Table 3-3 below (taken from Volume I of Hartlepool BC's Level 1 SFRA) shows the typical depths where certain mitigation measures would be applicable.

Table 3-3: Suggested Screening Criteria for Mitigation Measures	
Depth of Inundation*	Comments
0 to 1.0 m	Sustainable mitigation and flood risk management may be feasible for both housing and employment purposes. There is a greater likelihood that the Exception Test can be passed.
1.0 to 1.5 m	Mitigation is likely to be costly and may not be economically justifiable for low value land uses. Housing allocations are considered appropriate, provided flood risk can be managed or mitigated (e.g. by using lower levels for car parks or public areas). Floor level raising for employment purposes is unlikely to be economically viable and employment allocations should be reconsidered in favour of alternative lower risk sites. The likelihood of passing the Exception Test is lower.
Above 1.5 m	Flood risk mitigation measures are unlikely to be economically justifiable and both housing and employment allocations should be reconsidered in favour of alternative lower risk sites. Development is unlikely to be sustainable and the likelihood of passing the Exception Test is low.
Notes: * Based on predicted depth of inundation for the 1% (Fluvial) event + 20% additional flow for Climate Change as per PPS25. Environment Agency flood zone data.	

Tioxide site

The red outline in Figure 1-1 shows the Tioxide operational land. An extension to the Tioxide chemical works has recently been undertaken. Huntsman Tioxide could put forward this land for further extensions in the future but there are no plans to develop in this area in the short to medium term. The latest extension appears to have raised the ground from around 1.5m AOD to 3.5m AOD. 2m of ground raising has therefore taken place, putting the extension on the same level as the rest of the site. This puts the site 0.7m below the undefended 1 in 200 year flood level. This study will make recommendations if other parts of the site are put forward for development in the future.

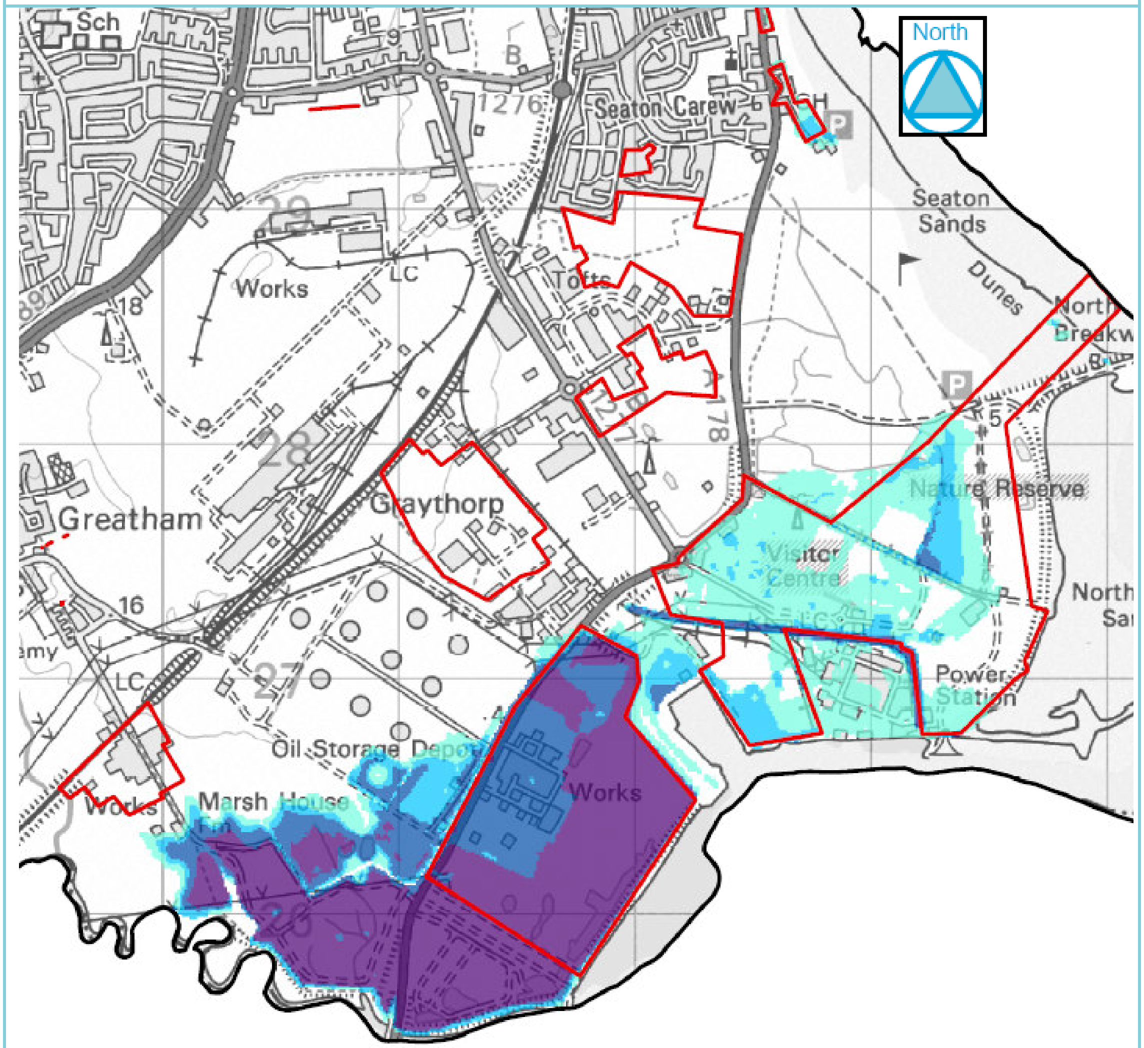
With defences in place, the Tioxide site does not flood until the 1 in 200 year plus CC event. However, Figure 3-9 shows that during the 1 in 200 year plus CC event, the Tioxide site is flooded to depths greater than 2m. This is because the area behind the defences is very low lying so fills to significant depths when the defences are overtopped or breached. Table 3-3 suggests that if further extensions were planned for the Tioxide site, flood risk mitigation measures are unlikely to be feasible.

However, this site is within the area of the existing chemical works and other industrial development. Significant land raising has taken place in the past, in order to make areas around the Tees Estuary developable. In addition, the preferred option for the Tees Tidal Strategy is to realign and improve the defences that protect the Tioxide site (and other areas). Due to the national importance of the Tioxide site and the inability to develop this site anywhere else, it is believed that a combination of land raising, flood resilience measures and some reliance on the existing flood defences could allow any further extensions to go ahead on flood risk grounds. However, there will be a significant cost involved with these measures.

The latest extension raised the land to 3.5m AOD. This is 0.7 below the 1 in 200 year level and around 1.7m below the 1 in 200 plus CC level. The defences may protect the site from the 1 in 200 and 1 in 1000 year flood events, but climate change will put the site at a risk.

The Environment Agency normally requires development to be free from tidal flooding during the 1 in 200 year level. This means that around 2.7m of ground and floor rising would be required (a significant amount). However, if more of the site comes forward for development, a breach assessment of the defences should be undertaken so that an acceptable mitigation strategy can be proposed. This may suggest a lower flood level or could recommend an improvement to the flood defences rather than significant ground raising.

Figure 3-9: Flood depths for the 1 in 200 year+ cc existing risk scenario at the Level 2 SFRA sites



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0 - 0.5
0.5 - 1
1 - 2
greater than 2

Proposed Nuclear Power Station

The nuclear power station site (see Figure 1-1) represents land that may be used for one of the UK's new nuclear power stations. This would be developed around the existing site, which is due to be decommissioned. The existing power station is shown to be defended (see Figure 3-7); the whole site has actually built on land elevated at around 4.6m AOD. Part of this may been due to manmade land raising, although the surrounding undeveloped land is at a similar elevation.

Flood depths in the proposed development area for the 1 in 200 year plus CC event, range from 0 to 1m, with the majority of the area at risk of depths of 0 to 0.5m. Table 3-3 suggests it should be possible to manage depths of this magnitude relatively easily. Due to the nature of the development, this should be achieved through ground and floor raising rather than relying on raised flood defences or flood resilience measures. This would keep the development dry during the extreme 1 in 200 year plus CC event.

The low flood depths are due to the limited tidal flow getting to the site as a result of the naturally higher ground at the existing nuclear power station and the North Gare sand dunes. With the dunes removed (undefended scenario), lower lying parts of the site to the north of the existing power station can flood to depths in excess of 2m (see Figure 3-5). The proposed nuclear power station site is therefore reliant on the relatively narrow width of protection offered by the North Gare sand dunes (see section 2.1.3 and 3.2 - 3rd paragraph). A more detailed FRA of the nuclear power station should consider the stability of the North Gare sand dunes and the flood depths and hazard if the dunes breached. The mitigation measures should be based on this scenario.

There would be no major problems with access and egress as the land to the west of the propose power station is elevated above the extreme tide flood levels.

Seaton Sands Commercial Development Site

At the 1 in 200 year plus CC event, the Seaton Sands SHLAA site floods to depths of between 0 and 1m due to overtopping of the sea wall and small crest wall. This site is not flooded during the 1 in 200 or 1 in 1000 year event. Although the site is flood free during the 1 in 200 year event, the development should be able to manage the risk from the 1 in 200 plus CC event. As the site is small and only a small part is at risk from depths above 0.5m, it seems reasonable that land and floor raising above this flood depth is the most practical option. A certain amount of land raising would already be required when constructing this undeveloped site. Alternatively, the small crest wall could be raised to above the 1 in 200 plus CC level. The wall is currently at 4.8m AOD. This would need to be raised by at least 300mm to 5.1m AOD (not including freeboard). The option of flood resilience measures designed into the ground floor of houses, up to the 1 in 200 year plus CC flood depth, is also available.

The high ground directly to the north and west of this site means that emergency access and egress will not be a major issue. At the detailed FRA stage, a wave overtopping assessment should be undertaken for this site, especially if the option of raising the crest wall is chosen.

3.3.3 Flood Hazard

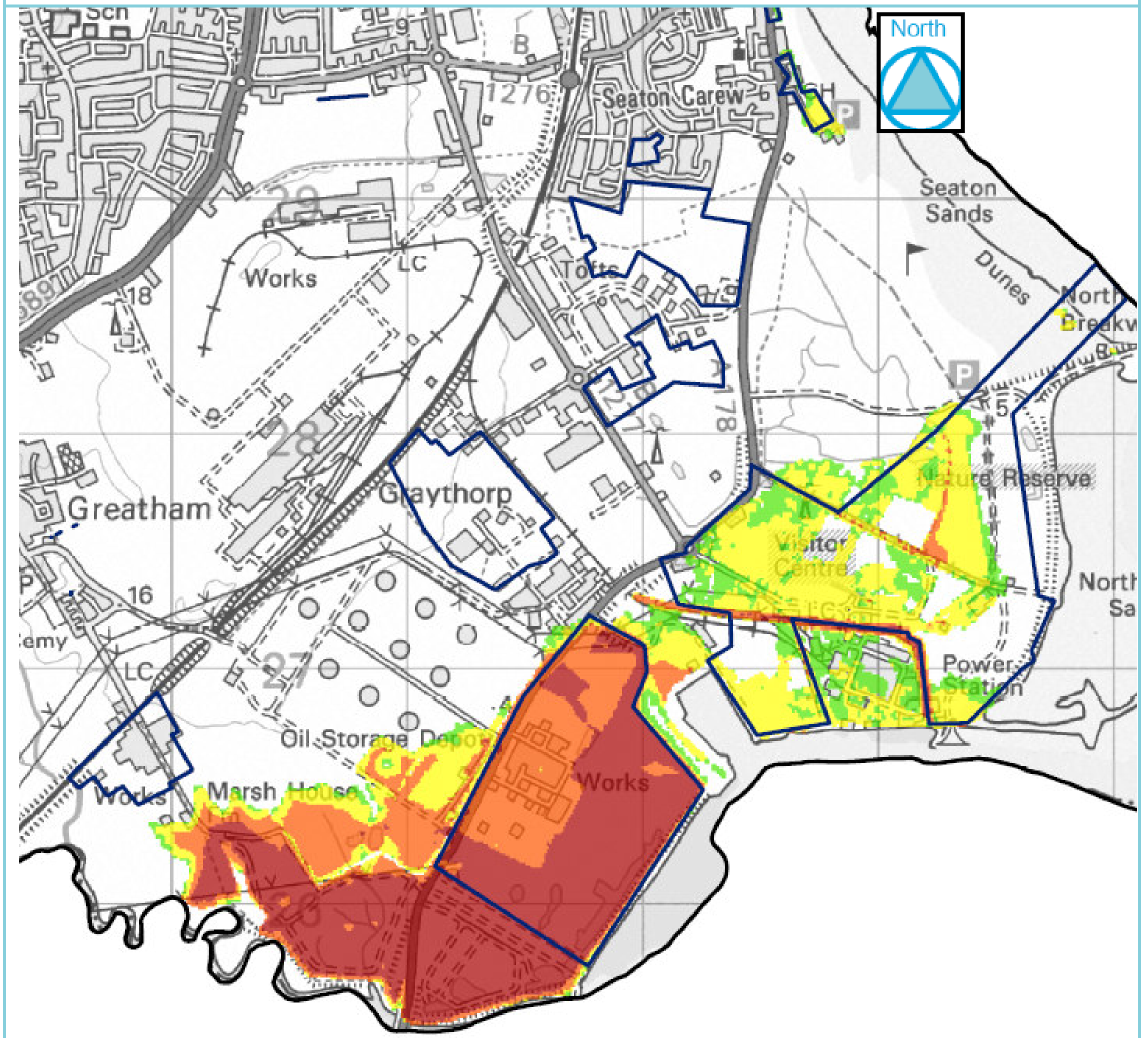
The existing risk flood hazard results for the 1 in 200 year plus CC event can be seen in Figure 3-10 below, full maps can be seen in Appendix A Figures A5 and A6.

General guidance from the Environment Agency is that maximum flood hazard emergency access and egress routes (which are used by the emergency services) should not exceed the depth and velocity (hazard) combinations associated with 'danger for most' (see Table 3-2).

For the existing risk scenario, the only location where this could be an issue is if further development is proposed in the Tioxide site area. Further expansion of the Tioxide site is not proposed in the short or medium term but if it were, land raising would be required and put the development outside of this risk category and into a lower, more acceptable category.

The proposed nuclear power station site would be a risk of higher flood hazards (than those shown in Figure 3-10) if the North Gare sand dunes breached. The hazard associated with this event should be considered at the detailed planning stage. Figure 3-4 shows the flood hazard if these dunes were removed. The low to moderate hazard shown in Figure 3-10 is due to the limited tidal flow reaching the site from the over topped Greenabella Sea Wall and via the higher land of the existing power station.

Figure 3-10: Flood hazard for the 1 in 200 year+ cc existing risk scenario at the Level 2 SFRA sites



- Caution
- Danger to Some People
- Danger to Most People
- Danger to All People

3.4 Summary

3.4.1 Flood Risk Assessment requirements for the Level 2 sites

Whilst the Level 1 SFRA focuses on delivering a strategic assessment of flood risk within Hartlepool BC, this Level 2 SFRA has gone one step further in investigating flood risk in more detail at specific allocations. This Level 2 SFRA has outlined which sites could be developed safely and what mitigation measures will be required to do this if they pass the Sequential Test. However, there is still a need for a site specific flood risk assessment (FRA) to resolve detail.

General FRA guidance for developers has been supplied within the Hartlepool BC Level 1 SFRA, which must be referred to (see Chapter 3 of Volume III). Elements of the FRA guidance are listed below:

- Appropriate land use in flood risk areas
- Undefended areas – flood risk mitigation
- Defended areas
- Wave overtopping
- Breaching of defences and sand dunes
- Public Safety and rapid inundation
- Feasibility of flood risk mitigation

Table 3-4 provides a summary of the tidal flood risks and the requirements for each site in order for development to go ahead safely. This table should be referred to when completing FRAs for the individual sites.

Some specific FRA requirements are listed below:

- Buildings should be structurally sound and remain in situ during the 1 in 200 year plus CC event (flood hazard). If development of the nuclear power station went ahead, a condition assessment of the North Gare sand dunes should be undertaken. Following this, a breach assessment should be undertaken so that the maximum hazard that the power station buildings would be exposed to could be ascertained.
- If further development within the Tioxide operational area is to take place, a similar assessment to that of the power station should be undertaken on the Greatham Creek flood defences and the Greenabella Sea Wall (condition assessment and breach assessment).
- Before development of the Seaton Sands development site, a wave overtopping assessment should be undertaken. The tidal modelling in this study has produced flood extents for the extreme flood events but it has not undertaken an assessment on the impact of waves which can flood sites which are elevated in excess of the extreme tide levels.

3.4.2 Emergency Planning

Appropriate emergency planning must be incorporated in any FRAs. Emergency planning can be a crucial tool in reducing the residual risk to both people and to lesser degree property. Current flood response plans must be considered if development is going to place a greater number of people in areas of high risk whether the actual risk can be managed or not.

Table 3-4 identifies where emergency access routes should be identified for the Level 2 SFRA sites as part of emergency planning measures.

PPS25 requires the LPA to make the final decision as to whether the Emergency Planning issues have been taken into account with their development plans. This specifically refers to emergency evacuation (access and egress). The approval of emergency planning procedures is not in the remit of the Environment Agency and specialist assistance may be required from Emergency Planners, Local Resilience Forums and the Emergency Services for approval.

Table 3-4: Site specific flood risk summary			
Site	**Undefended Risk**	**Existing Risk**	**Development requirements/options**
Century Park	Not at risk of flooding	Not at risk of flooding	Can allocate for development on flood risk grounds
Graythorp	Not at risk of flooding	Not at risk of flooding	Can allocate for development on flood risk grounds
Tofts Farm	Around half the site is at risk from the 1 in 200 yr plus CC event. A smaller section is at risk from the 1 in 1000 yr event. For the 1 in 200 plus CC event, flood depths would be between 0.5 and 1m. Flood hazard would be moderate.	Not at risk of flooding due to the natural defences of the North Gare sand dunes.	Can allocate for development. Only at risk from the 1 in 200 yr plus CC event if the North Gare sand dunes were breached. This is a possibility over the next 100 years due to the narrow width of protection. As flood risk to this site will only occur with the predicted 1 in 200 yr event in 100 years time (and if the dunes breached), mitigation measures shou8ld not be a requirement for this proposed industrial allocation as the life of the design life of the development is likely to be before the sea level rise affects the site.
Tees Road Seaton	Around half the site is at risk from the 1 in 200 yr plus CC event. A smaller section is at risk from the 1 in 1000 yr event. For the 1 in 200 plus CC event flood depths would be between 0.5 and 1m. Flood hazard would be moderate.	Not at risk of flooding due to the natural defences of the North Gare sand dunes.	Can allocate for development. Only at risk from the 1 in 200 yr plus CC event if the North Gare sand dunes were breached. This is a possibility over the next 100 years due to the narrow width of protection. As flood risk to this site will only occur with the predicted 1 in 200 yr event in 100 years time (and if the dunes breached), mitigation measures would not be required for this proposed industrial allocation.
Seaton Sands development site	Around half the site is at risk from the 1 in 200 yr plus CC event. A smaller section is at risk from the 1 in 1000 yr event. For the 1 in 200 plus CC event flood depths would be between 0.5 and 1m. Flood hazard would be moderate.	Around half the site is at risk from the 1 in 200 yr plus CC event. Flood depths would be between 0 and 1m for this event with a moderate to low flood hazard.	As only part of this site is at risk from the 1 in 1000 year undefended flood event (equivalent to Flood Zone 2), it should be possible to allocate this site on flood risk grounds. The 1 in 200 yr plus CC event existing risk should be mitigated against. The most straightforward way of managing this is by land and floor raising above the 1 in 200 yr plus CC flood depth (raised by around 0.5m). Alternatively, the crest wall could be raised by at least 300mm. A wave overtopping assessment would be required during the FRA for this site.
Tioxide land	If the Greatham Creek defences and Greenabella Sea Wall were not there, this area would be at risk from the 1 in 200 year event. Flood depths for the 1 in 200 yr plus CC event would be over 2m and flood hazard would be extreme.	With the flood defences in place, this area would only be at risk from the 1 in 200 yr plus CC event. However, the flood depths would still be over 2m and flood hazard extreme.	An extension of the Tioxide works has already taken place. Further expansion is not planning in the short and medium term. If expansion goes ahead in the long term, the site is at risk from deep hazardous flooding. Significant land raising (2-3m) and/or improving the flood defence would need to take place as the land is very low lying (around 1.5m AOD).
Nuclear Power Station	Two thirds of the site at risk from the 1 in 200 year event (if the North Gare sand dunes were removed/breached).	With the North Gare sand dunes in place, the area would only be at risk from	The proposed nuclear power station site is dependent on the North Gare dunes for flood protection. The site is also dependant on the Seaton Sands dunes, although breaching here is less likely. During the detailed planning stage, a more detailed assessment of

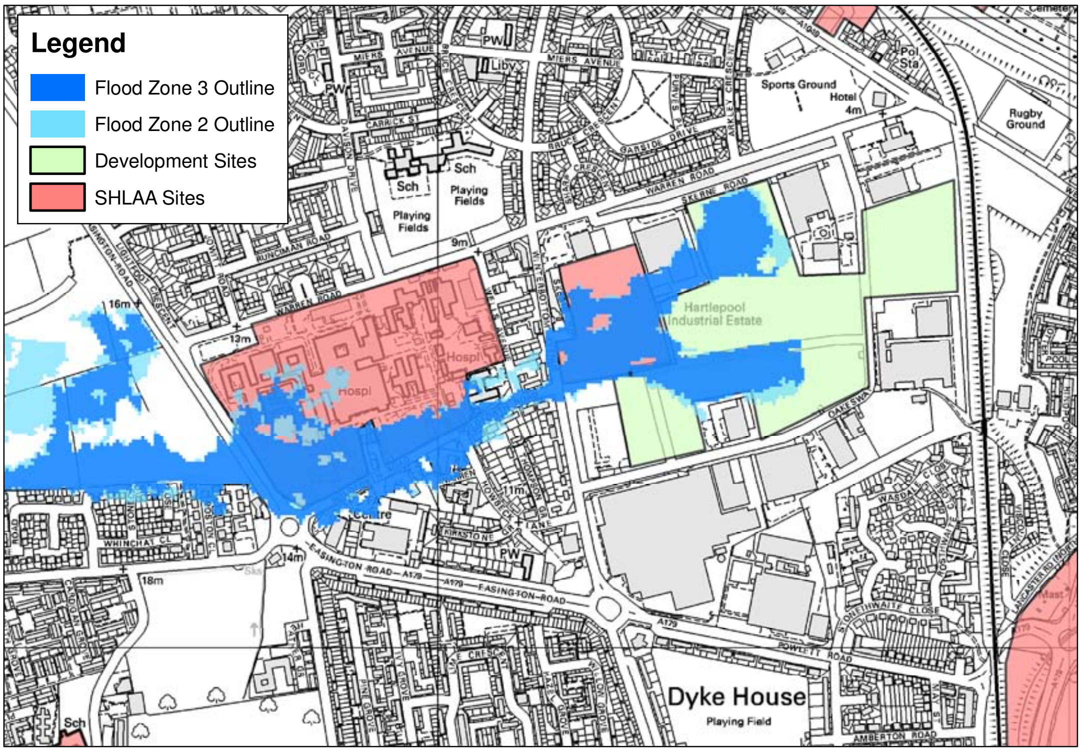
	The remainder of the site (which is on higher ground) is at risk from the 1 in 200 yr plus CC event. Parts of the site would have flood depths over 2m, the other parts 0 to 1m. Flood hazard ranges between moderate and extreme (depending on the elevation of the land).	the 1 in 200 plus CC event from a flood pathway passing over the existing power station and from overtopping/breaching the Greenabella Sea Wall. Due to the low volume of flood water, flood depths would be between 0 and 0.5m, flood hazard would be low to moderate.	the ability of the dunes to withstand an extreme tide event and the flood hazard caused by a breach should be undertaken. Any new power station should be resilient enough (structurally) to withstand a breach hazard. In order to mitigate the breach hazard and the depth of flooding if the dunes were removed, land raising would be required. Some parts of the site are at risk of flood depths over 2m (this part of the site is elevated at around 2m AOD). Less important/non operational parts of the site (e.g. car parks, open space) could be located in this low lying area (where the nature reserve is), otherwise, significant land raising would be required. 1-2m of land raising in other, higher parts of the site would remove flood risk from the site up to the undefended 1 in 200 yr plus CC flood event. Alternatively, part land raising and part flood resilience measures could be designed in. However, this would be dependent on whether flood resilience measures are possible for a nuclear power station.
See Figure 1-1 *for the location of the above sites*			

4. Hartlepool Hospital and Industrial Estate Assessment

4.1 Background

The Level 1 SFRA highlighted that the Hartlepool Hospital SHLAA site along with the Oakesway SHLAA sites and Industrial Estate development site are located within the existing Flood Zone 3 (see Figure 4-1 below) and recommended further work as part of the Level 2 SFRA to confirm the validity of the Flood Zone in this location.

Figure 4-1: Middle Warren Watercourse Flood Zones and proposed allocations



Flood risk to these development sites is a result of the Middle Warren Watercourse (MWW) overtopping Easington Road and following the natural topography of the site along Holdforth Road.

In reality the MWW drains into a large culvert known as the North Area Main Drain (NAMD) immediately to the west of Easington Road. The NAMD runs in a northerly direction adjacent to Easington Road before heading north eastwards and draining into the North Sea.

A review of the existing Flood Zone maps suggests a broad scale mapping methodology appropriate for open channels has been adopted i.e. all flows up to QMED remain in bank. If this is the case then it is inherent in the outline that the capacity of the culvert is equivalent to QMED.

The Level 2 SFRA has reviewed the flood risk to the site given the existence of the NAMD.

4.2 Hydrology

The hydrology for the MWW to the culvert inlet into the NAMD has been derived using Version 3 of the Flood Estimation Handbook (FEH).

Peak flows have been calculated using the statistical methodology. Flow hydrographs have been developed using the ReFH methodology and scaled to the calculated peak flows (see Table 4-1).

Table 4-1: Flood peak (m^3/s) for the following return periods (in years)

2	5	10	25	50	75	100	200	1000
0.72	1.02	1.24	1.58	1.89	2.09	2.24	2.66	3.83

It has been noted that the MWW drainage catchment contains the Throston Grange reservoirs and peak flows will be heavily influenced by these. The pooling group analysis reflected the fact that there are few small gauged catchments with a large reservoir influence. The calculated peak flows may not therefore fully reflect the attenuating effects of the reservoirs and could be conservative.

4.3 Modelling

4.3.1 Culvert Inlet Capacity

As detailed previously, flooding of the development sites is a result of flood waters backing up at the MWW inlet to the NAMD and overtopping Easington Road.

The capacity of the culvert inlet has been calculated assuming a peak ponded water level equivalent to the lowest flow pathway between MWW and the development sites. This has been extracted from LIDAR data and is approximately 15.35m AOD.

Site visits and photos of the culvert inlet show that the trash screen covering the inlet is prone to blockage, see Figure 4-2. A range of blockage scenarios have been assessed based on the CIRIA Culvert Design and Operation Guidance (2010) and an assessment of the level of blockage apparent during the site visit. Table 4-2 details the peak discharge into the NAMD for a range of blockage scenarios.

Figure 4-2: Middle Warren Watercourse Culvert Inlet Trash Screen

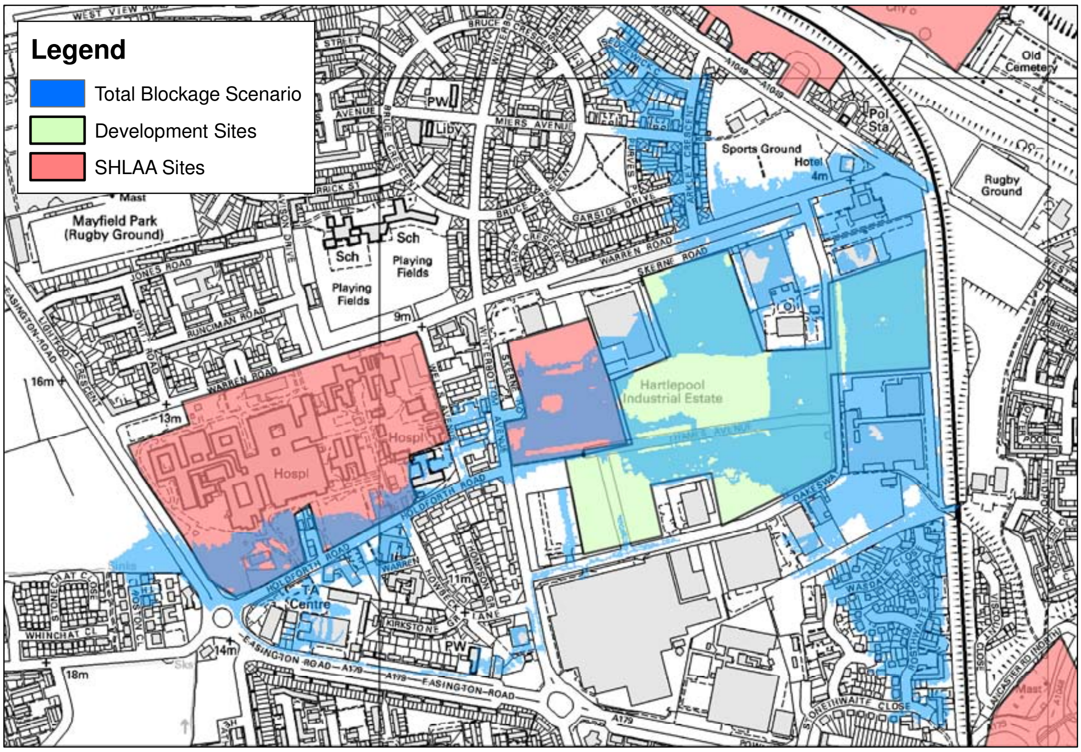
Table 4-2: Peak discharge (m^3/s) for the following blockage scenarios			
0%	30%	67%	95% (as observed on the site visit)
3.87	3.64	3.34	0.56

The analysis shows there is a sufficiently large capacity to discharge up to the 200 year flood event even with a significant volume of debris on the trash screen. This reflects the fact that up until a blockage of approximately 70% the culvert inlet and not the trash screen is the critical structure.

However blockage during the site visit was significant and based on observations a discharge capacity of less than the 2 year design event could be more applicable. Once this level of blockage is present during a flood event total blockage of the screen is a reasonable assumption.

Following discussions with the Environment Agency the impact of a total blockage scenario has been assessed. In this scenario all flow has been assumed to overtop the culvert. Results are detailed in Figure 4-3.

Figure 4-3: Middle Warren Watercourse Total Blockage Scenario



The total blockage scenario is larger than the existing Flood Zone highlighting the importance of the effective operation of the trash screen in managing flood risk.

4.3.2 North Area Main Drain Capacity

Information from NWL detailing the extent of the NAMD drainage catchment was not made available for the purposes of this study and hence it has not been possible to estimate design flows to the MWW culvert inlet. A conservative estimation of the likely drainage catchment however suggests it will be limited to the south by Tunstall Farm Beck. This would restrict the catchment to an area of approximately 5 km^2 compared to the MWW drainage catchment, which is approximately 3.5 km^2.

The NAMD dimensions increase at the MWW culvert inlet from 2750 x 2550 mm to 2750 x 2800 mm. By using this change in dimensions and assuming maximum flow capacity occurs in the upstream NAMD culvert, it will be possible to assess the spare capacity of the NAMD immediately downstream of the MWW culvert inlet and confirm if the NAMD contributes to flood risk.

A number of smaller storm water sewers discharge into the NAMD in the vicinity of the MWW. It is considered that these catchments will have a significantly shorter time to peak than the MWW catchment and therefore a minimal impact on the capacity of the structure to mitigate flood risk to the development sites.

The analysis uses the methodology outlined in the Tables for the Hydraulic Design of Pipes Sewers and Channels (HR Wallingford 1994) and is based on the structural dimensions of the culvert and its gradient only. Results for a range of hydraulic roughness values are shown in Table 4-3.

Due to the hydraulic interactions that occur when the pipe is flowing full, the discharge capacities calculated will be lower than the maximum free surface pipe flow in the same pipe. The pipe constriction inherent in the flows detailed in Table 4-3 will therefore only occur at flows in excess of the maximum free surface pipe flow. The free surface pipe flow assuming a flow depth 2/3rds of the pipe height and a poor pipe condition is approximately 24 m^3/s.

Table 4-3: Capacity of NAMD for Varying Equivalent Sand Roughness Values			
Ks Value (mm)	U/S NAMD Capacity (m^3/s)	D/S NAMD Capacity (m^3/s)	Outstanding NAMD Capacity (m^3/s)
0.3 (Good Condition)	17.8	20.1	2.3
0.6 (Normal Condition)	16.7	18.9	2.2
1.5 (Poor Condition)	15.2	17.1	1.9

The results indicate that unless the condition of the NAMD is poor then there is sufficient capacity to discharge the 100 year design event.

4.3.3 Summary of Risk to Development Sites

An analysis of the capacity of the MWW culvert inlet and the NAMD has been completed using available data.

In the absence of catchment data a conservative approach to the assessment of the capacity of the NAMD has been adopted. Generally, the results from this approach indicate the outstanding capacity within the NAMD will be sufficient to manage the 100 year design event from MWW.

Given the data limitations, some uncertainty remains regarding the outstanding capacity of the NAMD. For that uncertainty to be valid the following assumptions must be true;

- the drainage catchment must be of a sufficient area to deliver in excess of 24 m^3/s
- the upstream surface water system must have sufficient network capacity to discharge 24 m^3/s into the NAMD in the vicinity of the MWW culvert inlet
- the condition of the NAMD must be poor

Based on the above it is considered that the uncertainty in this analysis is low and that the NAMD will not contribute to flood risk.

The analysis shows that flood risk to the development sites is significantly affected by the level of blockage on the trash screen. Managing the risk of blockage to the trash screen will reduce the risk of flooding.

4.4 Trash Screen Management

The assessment has highlighted the importance of maintenance and the removal of the debris build up on the MWW culvert inlet trash screen.

It is understood that maintenance of the trash screen is currently the responsibility of Bellway and Persimmon Homes, the developers of the Middle Warren residential estate. No details of the maintenance programme are available but site visits completed over the duration of the study suggest there is an issue. Blockage of the trash screen could be attributed to either an inappropriate maintenance programme or a trash screen design that is unable to accommodate the volume of debris in the channel. If the latter is true then the trash screen is likely to become completely blocked during a design event and no improvements to the maintenance regime will prevent this.

A number of options are available to mitigate the risk of debris building up on the trash screen. These include:

- Improved maintenance regime

- Installation of a trash screen with a lower propensity to block, i.e. greater bar spacing or multi stage screen,
- Installation of a security fence as an alternative option to the trash screen, however this will have to coincide with public health and safety requirements

The capacity of the NAMD suggests there is a minimal risk of a blockage occurring as a result of debris in the culvert. The primary purpose then of the trash screen would appear to be security and public health and safety. The drop from the bed level of the MWW to the invert level of the NAMD is in the region of 5 m so a security screen is clearly needed. There is however some scope for considering a fence if it is felt the risks can be managed sufficiently.

4.5 Conclusion

The existing Flood Zone outlines indicate the Hartlepool Hospital SHLAA site along with the Oakesway Industrial Estate development site are at risk of flooding. The flooding mechanisms to the site are attributed to debris build up on the trash screen of the MWW culvert inlet to the NAMD.

The analysis of flood risk has been completed using available data and appropriate assumptions. If there is no debris build up on the trash screen, then there is sufficient capacity in this system to discharge the 100 year design event through the NAMD. The development sites in this scenario would therefore not be at risk of flooding.

Where a significant build up of debris is present on the trash screen, the development sites are at risk of flooding. This residual risk can be managed through a range of options including maintenance or improvements to the trash screen design.

5. Critical Drainage Areas

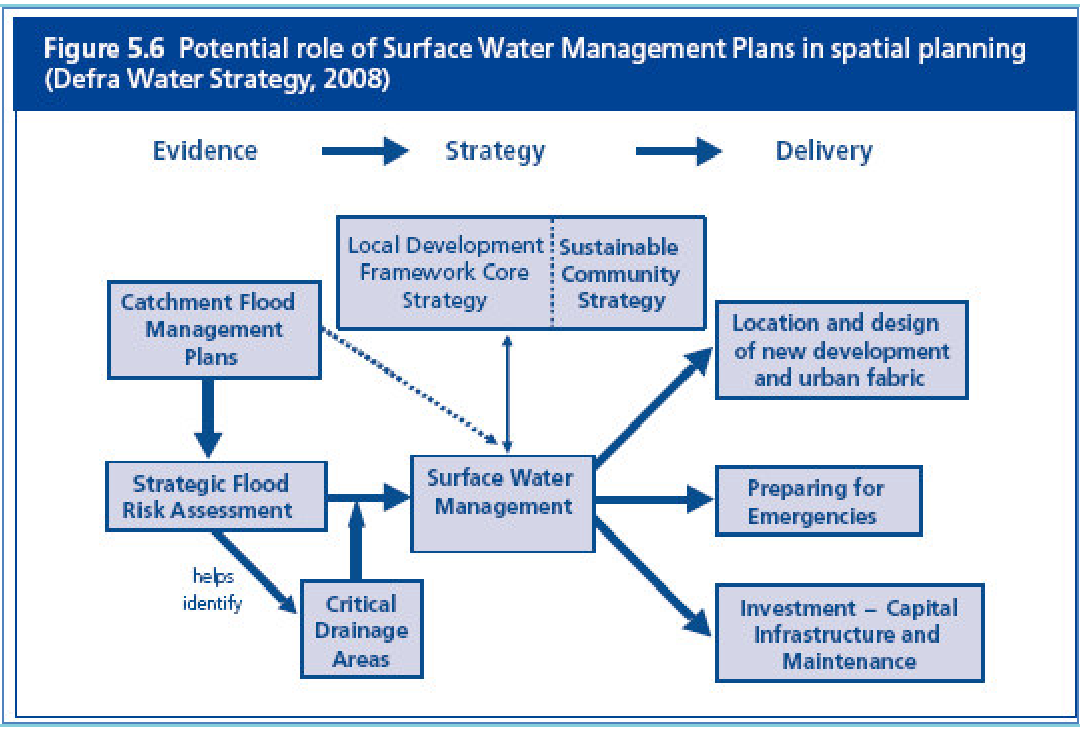
5.1 Introduction

During the Level 1 SFRA, historical surface water flooding incident data was collected from Hartlepool Borough Council (HBC) and the Hartlepool Integrated Urban Drainage (IUD) project (Mott Macdonald 2008). This data was then used to validate the Environment Agency's Areas Susceptible to Surface Water Flooding Maps, a national dataset showing potential surface water flooding extents. The surface water zones are based on a broad scale modelling approach and should only be used for strategic and emergency planning purposes.

Using the above data, the Level 1 SFRA identified 'candidate' Critical Drainage Areas (CDAs). CDAs are those areas at significant risk from surface water flooding or subject to potential large changes in runoff due to development. PPS25 Practice Guide states that SFRAs should provide the evidence and recommendations for LPAs to understand the need for a Surface Water Management Plan (SWMP) by identifying Critical Drainage Areas (CDAs) within their borough.

Figure 5-1, taken from the PPS25 Practice Guide, shows how SFRAs link to SWMPs and then to overall spatial planning.

Figure 5-1: Extract from PPS25 Practise Guide showing role of SWMPs in Spatial Planning



The candidate CDAs have been investigated further within this Level 2 SFRA using:

- Detailed surface water mapping
- Site visit and consultation with HBC

Following discussions with NWL, no further data in addition to that provided for the Level 1 SFRA was made available for the development of CDAs and future consultation will be critical as part of the SWMP process. The final allocation of CDAs however is based on the best available data and should be used as the starting point of the investigation for the SWMP.

The proposed CDAs are discussed in further detail in Section 5.3.

5.2 Detailed Surface Water Mapping

As part of the allocation and finalisation process of CDAs and to gain a better understanding of surface water flooding in Hartlepool, detailed surface water mapping has been carried out.

JFLOW, a 2D modelling software developed by JBA, was used to route rainfall over a digital terrain model. This is the same software used to produce the Environment Agency's Areas Susceptible to Surface Water Flooding maps (see Section 3.6 of Volume II Level 1 SFRA), however the following improvements were made to the methodology:

- LIDAR data was used for the elevation model where available;
- The elevation model was modified via MasterMap data to include roads and buildings to help define flow paths;
- The run-off from the surface was varied depending on whether an area was developed or green space, to take into account the variation in infiltration (water being absorbed by the ground);
- An extreme 1 in 200 year rainfall event with a storm duration of 1 hour was chosen; and

From the detailed modelling, three flood outlines were produced:

1. Less susceptible to surface water flooding,
2. Intermediate susceptible to surface water flooding, and
3. More susceptible to surface water flooding.

Most new sewers are designed to a 1:30 year design standard and hence sewer flooding problems will often be associated with more frequent storm events when a sewer becomes blocked or fails. In the larger events, surface water will significantly exceed the capacity of the sewer system and flow across the surface of the land. In these scenarios it is considered appropriate to view the flood alleviation benefits of the sewer network as limited and assume all flow is overland.

The surface water modelling and mapping, which is based on an extreme scenario, picks up overland flow paths that would be expected should the sewers surcharge (back up) or gulleys block.

Considering both sewer and surface water flooding together is considered to be appropriate when taking a strategic view of flood risk in an extreme event from both these sources.

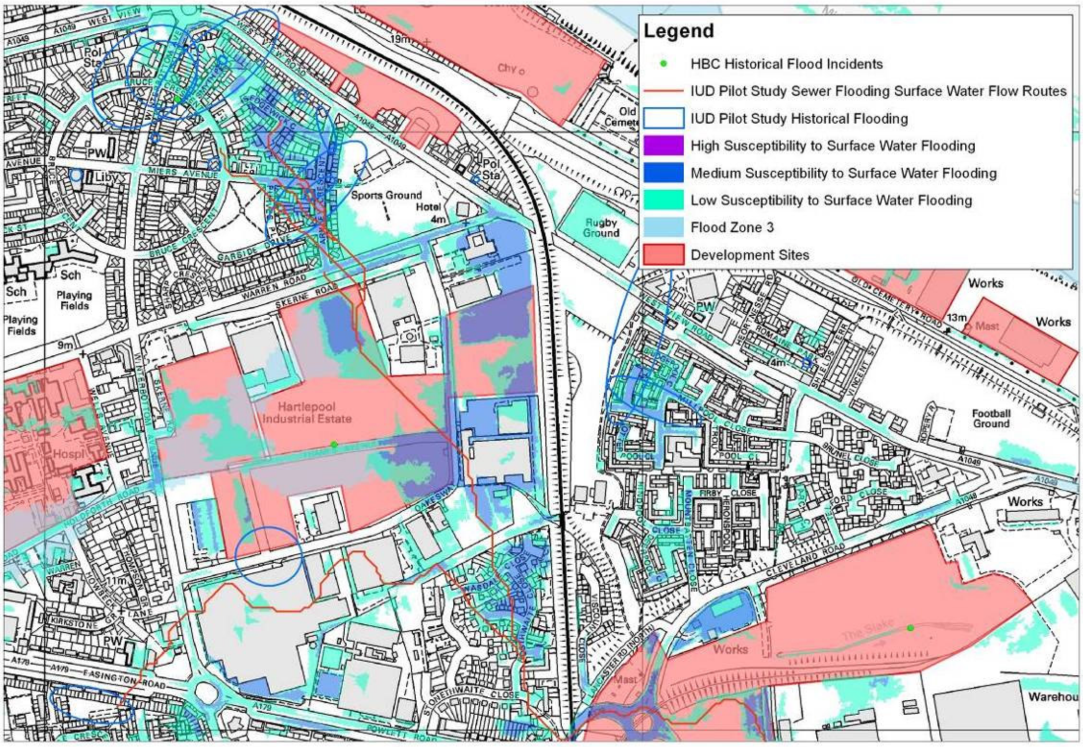
This detailed surface water mapping has been used to verify the candidate CDAs and larger surface water flooding locations which were initially identified using the Areas Susceptible to Surface Water Flooding maps (see section 5.3 below). Plans showing the detailed surface water mapping can be seen in Appendix A Figures B1 to B7.

5.3 Critical Drainage Areas

5.3.1 Slake Watercourse

The Slake Watercourse was identified as a candidate CDA in the Level 1 SFRA and has been confirmed as a CDA as part of the Level 2 SFRA. Figure 5-2 provides an overview of the flood risk information available at the site.

Figure 5-2: Slake Watercourse Flood Risk Overview



The Slake Watercourse has been heavily developed and its drainage catchment is now limited to two surface water networks that join within the Oakesway Industrial Estate.

The extent of the Flood Zone outline in this area has been discussed in Section 4 along with proposed approaches to its management and offers HBC a quick win opportunity through improvements to the MWW culvert inlet trash screen.

A number of the recorded flood incidents to the north of the Industrial Estate were related to the blockage of the overflow from the Brus pumping station. This was identified as a problem in the Level 1 SFRA but the overflow has since been cleaned.

Figure 5-2 suggests the outstanding issues in this area are related, to some extent, to the sewer network surcharging (red lines on the plan) but also to the location of the site immediately adjacent to the railway line. The railway line is potentially acting as a barrier to surface water flow and causing problems in the estate. Figure 5-2 also shows some historical flooding in Millpool Close to the east of the railway line.

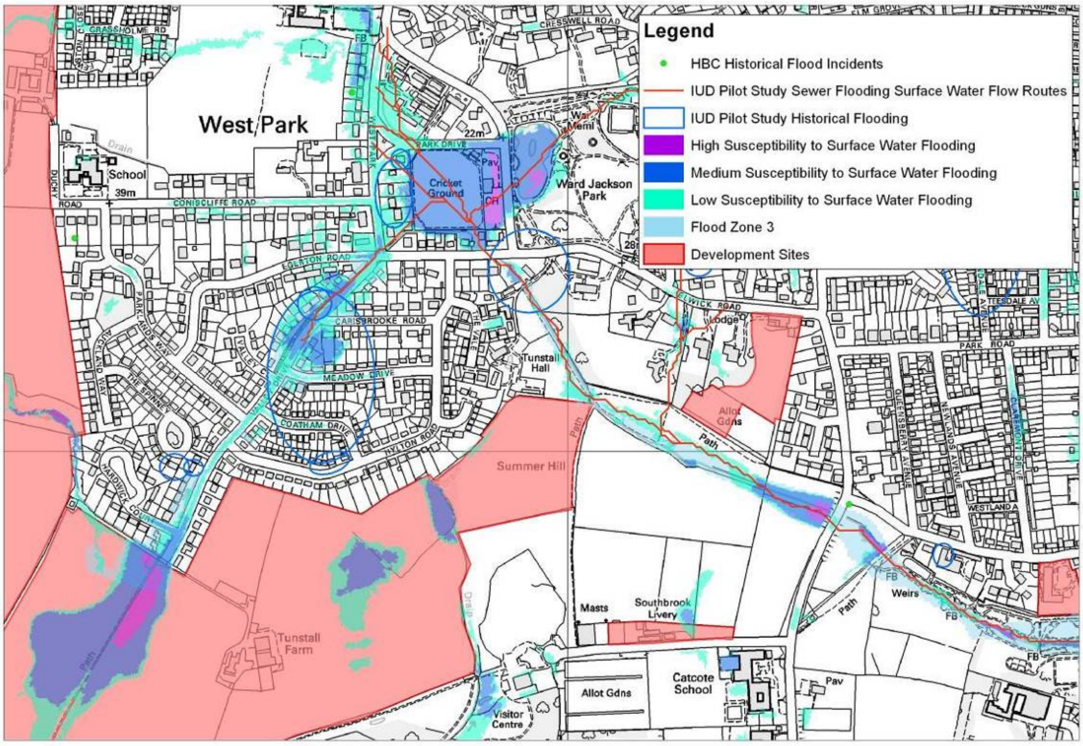
The SWMP will need to confirm the capacity of the flow routes passing the railway line and assess the scope to divert overland flow to these locations.

Downstream of the railway the Slake enters into a balancing pond designed to manage fluctuations in water levels due to tidal effects. There would therefore appear to be some opportunity to relieve upstream surface water pressures by increasing the pass forward flow from the Oakesway Industrial Estate and Millpool Close sites. The pond is located within a planning allocation and the implications of this will need to be discussed with HBC.

5.3.2 Tunstall Beck - Valley Drive

Tunstall Beck - Valley Drive was identified as a candidate CDA in the Level 1 SFRA and has been confirmed as a CDA as part of the Level 2 SFRA. Figure 5-3 provides an overview of the flood risk information available at the site.

Figure 5-3: Tunstall Beck - Valley Drive Flood Risk Overview



Flood risk along Tunstall Beck is associated with a series of access routes and culverts along Valley Drive which surcharge and cause flood waters to exceed bank top and flood local properties. The IUD pilot study also documented issues with the capacity of the combined sewers running along West Park reflected by the sewer flooding overland flow routes shown in Figure 5-3, and suggested there are associated water quality issues with this flooding

The wide range of issues at this site will require an integrated approach to management and thorough consultation with all key stakeholders.

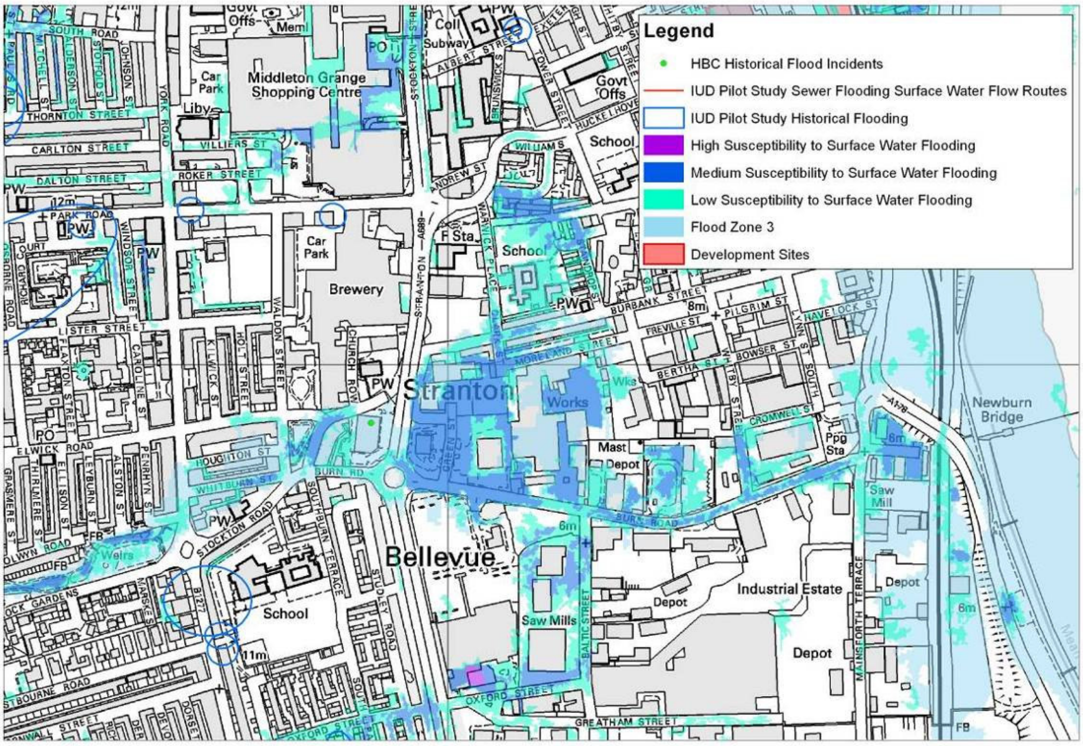
The Tunstall Farm Beck Pre-feasibility Study (JBA 2006) recommended the installation of online and offline storage ponds at sites further upstream. This solution has the benefit of relieving pressures on the downstream system. Key points to consider will be the negative impacts of the development of upstream sites and the potential use of increasing downstream capacity to alleviate the sewer flooding problems mentioned above.

This site offers HBC a clear opportunity to stream line the SWMP process and focus on the delivery of solutions. The SWMP will need to consult with NWL and confirm the scope for incorporating or at least appreciating the impact of improvements to the sewer system into the solution.

5.3.3 Tunstall Beck - Stranton

Tunstall Beck - Stranton was identified as a candidate CDA in the Level 1 SFRA, further work is required as part of the SWMP before this site can be confirmed as a CDA. Figure 5-4 provides an overview of the flood risk information available at the site.

Figure 5-4: Tunstall Beck - Stranton Flood Risk Overview



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Tunstall Beck enters a large diameter culvert beneath York Road which drains eastwards towards the coast. It then drops into a combined sewer which runs along Burn Road to the coast. At its downstream extent the entirety of the flow from the Tunstall Beck and the catchment area of the combined sewer is pumped southwards to treatment works at Seaton Carew.

An overflow system exists at the pumping station into the Coronation Drive road drain allowing discharge to the outfall at Newburn Bridge during periods of high flow.

Figure 5-4 shows both Flood Zone 3 and the surface water flood map affecting Stranton. The areas at risk of flooding appear to reflect the original alignment of Tunstall Beck yet no historical flood incidents have been collected in the area to confirm this.

During the development of Flood Zone 3 an estimate of QMED was used to account for the presence of the culvert. For the surface water flood map the capacity of the sewer system is assumed to be negligible in large flood events. In both these cases the significance of the large diameter culvert is likely to have been underestimated, therefore risk could be overestimated

The SWMP should review the capacity of the culvert, the combined sewer, the Coronation Drive pumping station and the Newburn Bridge Bridge outfall to confirm the existence of flood risk at this site.

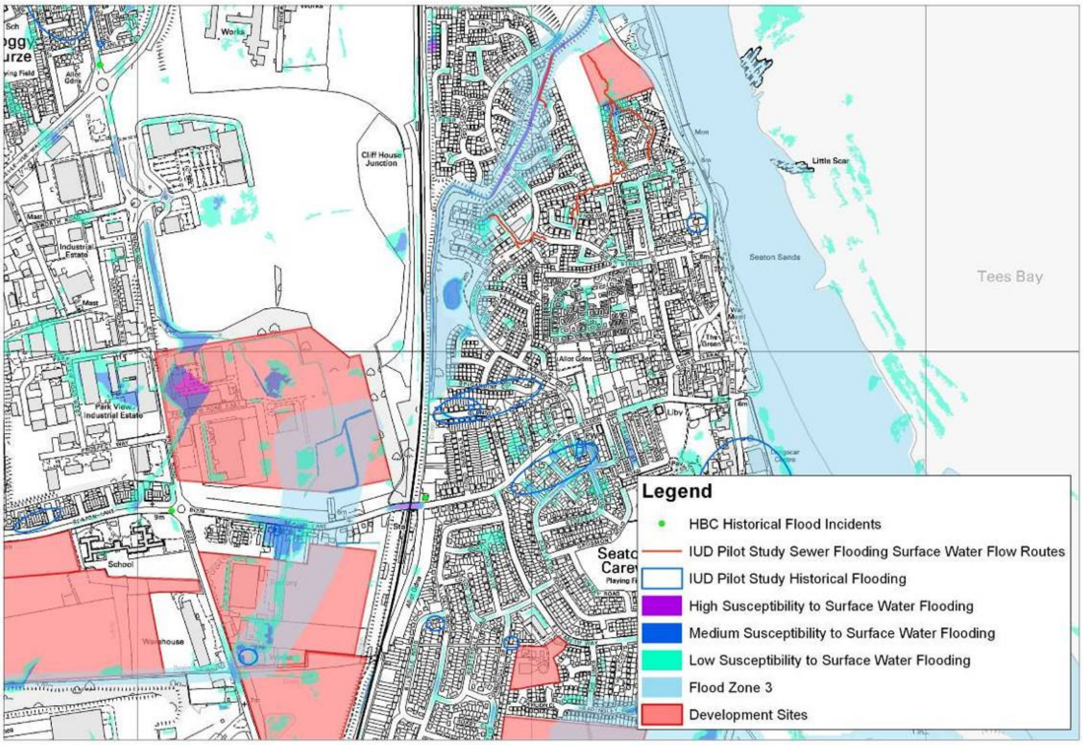
If it is found that the existing flood risk outlines are not representative of actual flood risk then it may be possible to remove the site from further consideration. If the flood risk outlines are valid then further work may be needed.

Potential options for consideration could include the utilisation of the natural flow paths through Stranton along Burn Road to facilitate discharge of surface water to the sea or the separation of Tunstall Beck from the combined sewer to allow discharge direct to the sea. This second option could relieve pressure on the Coronation Drive pumping station and provide additional water quality benefits by reducing the frequency with which the Newburn Bridge overflow is utilised.

5.3.4 The Stell

The Stell was identified as a candidate CDA in the Level 1 SFRA and has been confirmed as a CDA as part of the Level 2 SFRA. Figure 5-5 provides an overview of the flood risk information available at the site.

Figure 5-5: The Stell Flood Risk Overview



The source of the Stell is a large balancing pond designed to manage runoff from the Steel works located to the west. From here it drains northwards and enters a culvert beneath an industrial estate where it splits into the Old and New Stell.

At this it is joined by a small watercourse flowing from Golden Flatts to the west. Flooding incidents have occurred historically where the drain enters a culvert beneath the B1277. Site visits suggest that this culvert is undersized, particularly compared to the capacity of the Stell immediately downstream.

The Stell continues through Sovereign Park as the New and Old Stell before re-joining beneath the railway line again and flowing towards the sea.

Figure 5-5 shows large areas of Sovereign Park within Flood Zone 3. These zones were produced some time ago and may not consider the capacity of the New Stell. Downstream of the railway line flood risk is predominantly tidal. Figure 5-5 also shows a couple of sites where overland flow from the sewer system occurs.

This site provides the SWMP the opportunity of a quick win by reviewing the capacity of the B1277 culvert and reducing the frequency with which the culvert is overtopped. The surface water map suggests overtopping in this location would drain to properties along Seaton Lane and the scheme could potentially benefit these properties as well.

The Level 1 SFRA also refers to drainage issues in Seaton Carew. Further discussions will be required as part of the SWMP process with NWL to confirm if these are still outstanding and to consider the implications of the overland flow from the sewer system.

5.3.5 Additional Surface Water Flow Routes

In addition to the sites identified as part of the Level 1 SFRA a number of additional areas have been specified following the production of the improved surface water flood maps.

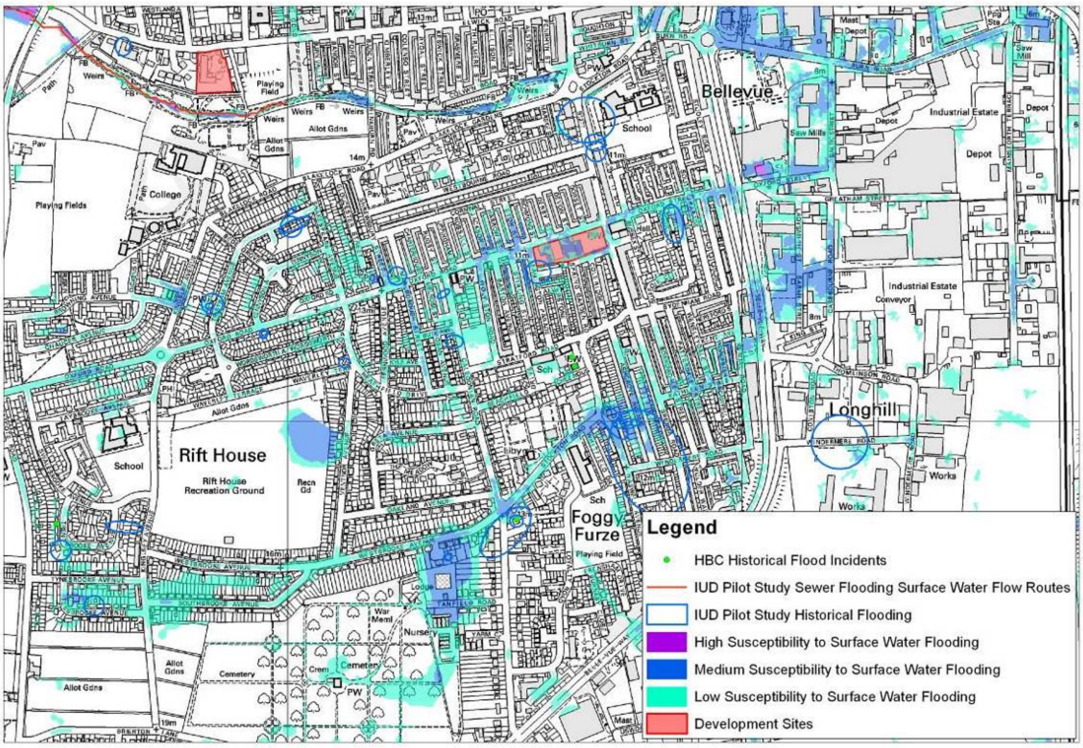
These sites do not fall within the fluvial and tidal Flood Zones but rather indicate natural overland drainage pathways within Hartlepool which also coincide with historical incidences of flooding collected. It is therefore assumed that the sites are at risk of surface water flooding.

Whilst it will be important to consult with NWL as part of the SWMP process to gain an understanding of the historical flooding incidents and the sewer capacity in these areas, flood risk in these areas is not necessarily the responsibility of NWL as it relates to events in excess of reasonable sewer system capacities. Solutions at these sites will need to focus on managing overland flows. The development of Green Infrastructure in relation to this is discussed further in Section 5.4.

Oxford Road and Westbrooke Avenue

Figure 5-6 provides an overview of the flood risk information available at the site.

Figure 5-6: Oxford Road and Westbrooke Avenue Flood Risk Overview



The natural drainage routes for surface water flooding at these sites are along road networks and it should be possible to undertake minimal works to further encourage this situation and reduce flood risk to local properties.

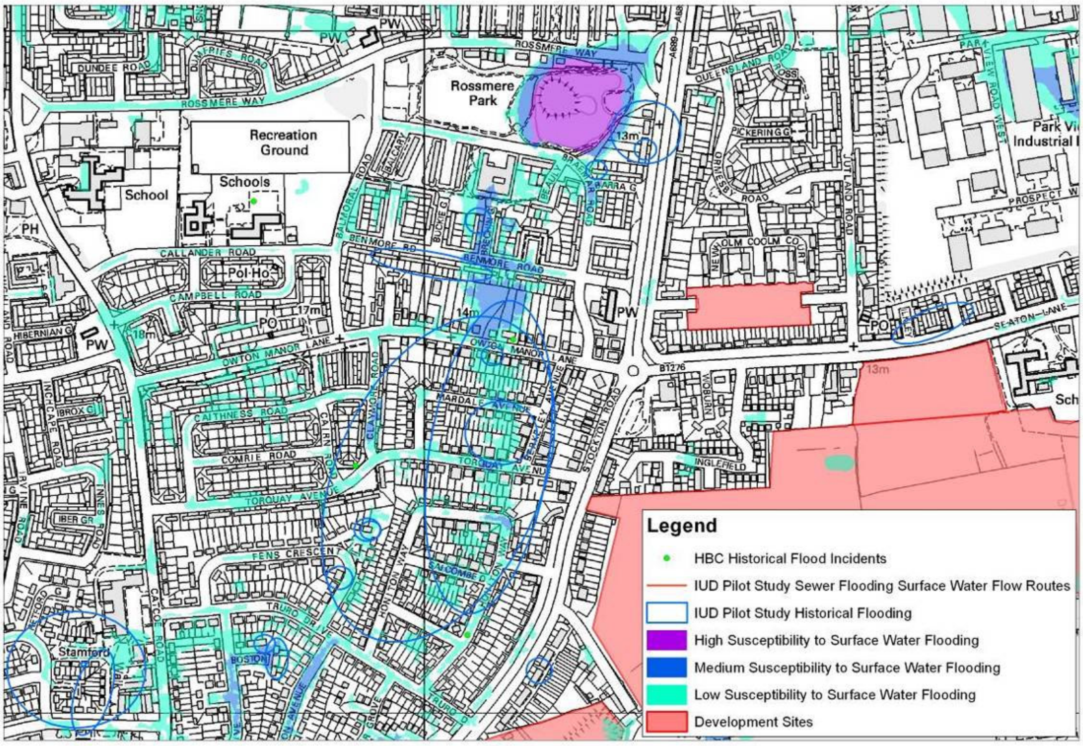
The Westbrooke Avenue drainage route becomes problematic at the eastern end of Stockton Road where it continues through a number of residential estates. The location of the Foggy Furze playing field may provide an opportunity to manage this risk.

The management of surface water flooding along Oxford Road could consider directing flows towards Tunstall Beck. The SWMP would need to consider this possibility within the scope of the Tunstall Beck - Stranton CDA.

Torquay Avenue to Benmore Lane

Figure 5-7 provides an overview of the flood risk information available at the site.

Figure 5-7: Torquay Avenue to Benmore Lane Flood Risk Overview



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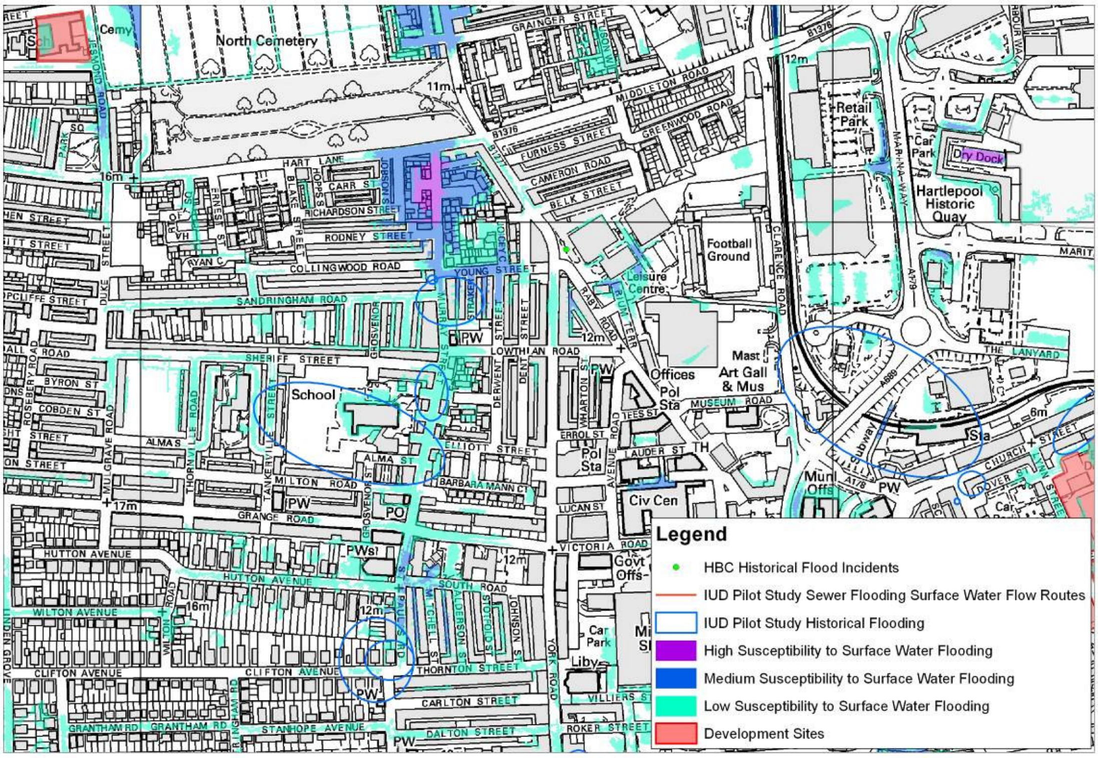
The natural topography in this area suggests surface water will run northwards through a series of residential estates. There is no obvious overland drainage route to mitigate the risk to these sites although Rossmere Park located to the north could potentially offer some Green Infrastructure opportunities.

Murray Street

Figure 5-8 provides an overview of the flood risk information available at the site.

Figure 5-8: Murray Street Flood Risk Overview



The natural drainage route at this site is northwards along Murray Street. The low point is to the south of Hart Lane and ponding in this location could affect a number of properties.

As part of the SWMP solutions could look at formalising the overland flow routes along Murray Street and allowing flows to discharge beyond Hart Lane and pond within the open area to the north.

5.3.6 Approach to SWMP

The Level 2 SFRA has reviewed the candidate CDAs and discussed in some detail the flood risk issues associated with each of these. There exists a substantial amount of readily available data to the SWMP provided in both the Level 1 and Level 2 SFRAs.

Based on the above there is the real opportunity for the SWMP to quickly focus on the critical issues and address in detail the majority of problems at a minimum cost.

Whilst some level of high level assessment and stakeholder engagement will be required as part of the early stages of the SWMP it will be important to minimise this phase of the works so as not to repeat work already completed and maximise the expenditure on solution development.

5.4 Green Infrastructure Opportunities

The Tees Valley has a Green Infrastructure Strategy which promotes the integration of flood risk management measures with improving the quality of local community environments. It is seeking to develop a linked network of green corridors and green spaces by 2021 which provide multiple benefits throughout Teeside.

Green Infrastructure (GI) is a useful term to describe a concept and has certain key characteristics associated with it. The first of these is Sustainability. The GI approach is seeking through planning and delivery to achieve:

- Economic benefits and opportunities
- Social benefits
- Environmental outcomes

GI is characterised by multiple functions and multiple benefits. A GI approach is seeking to plan, design and or manage more than one function in the landscape to get the maximum benefits from any investment. For this multiple function and multiple benefits approach to be successful requires multiple agency and community involvement to ensure all the potential beneficial outcomes are captured at the start of any planning process.

GI 'functions, benefits and values' have been researched around the country and 11 clearly definable economic benefits arising from investment in GI have been identified. These are:

1. Climate change adaptation and mitigation
2. Flood alleviation and water resource management
3. Quality of place
4. Health and well being
5. Land and property value
6. Economic growth and investment
7. Labour productivity
8. Tourism
9. Recreation and leisure
10. Landscape and biodiversity
11. Products from the land

The GI approach and flood risk planning this is best approached spatially. There is a hierarchy of spatial scales in planning all land use, development and infrastructure. Broadly, these can be recognised as being undertaken at the regional scale, district scale, neighbourhood scale and site specific scale.

This approach is supported by government policy. PPS25 invites responsible parties to make 'the most of the benefits of GI for flood storage, conveyance and sustainable urban drainage systems'. Planning Policy Statements, Regional Spatial Strategy's, sub-regional Action Plans and the emerging Integrated Regional Strategy's all provide policy support for planning investment in GI.

A summary of the main priorities and actions for Hartlepool BC from the Tees Valley Green Infrastructure Strategy are listed below.

Saltholme to Cowpen Bewley, Wynyard and Hartlepool

- Protect, enhance and create habitats in accordance with the objectives of Saltholme Nature Reserve, SSSI/SPA objectives, and LBAP priorities
- Investigate scope for further planting between Billingham and Hartlepool, and link with Cowpen Bewley Woodland Park
- Develop strategic access routes, particularly from residential areas of north Billingham and south Hartlepool and adjacent employment areas
- Implement the N Gare to Greatham section of the Hartlepool rural cycle way/walkway
- Develop a cycle route between Greatham and Cowpen Bewley
- Investigate potential for estuarine woodland creation
- Incorporate proposals for improving the environment of the Southern Industrial Zone in Hartlepool

Saltholme to Hartlepool Coast

- Protect, enhance and manage statutory nature conservation sites, and improve adjacent areas to support interest features of the SPA
- Develop a cycle route between N Gare and Transporter Bridge
- Investigate opportunities to enhance the railway corridor on the southern approach to Hartlepool
- Complement proposals for improving the visitor attraction of Seaton Carew
- Protect and enhance non-statutory (local) nature conservation sites
- Investigate potential for improving access, particularly new cycle ways and footpaths

Summerhill, North West Hartlepool and Hartlepool Western Fringe

- Develop high quality green link from Victoria Harbour and Marina through the town centre towards Summerhill Gateway site and the surrounding countryside
- Integrate with green infrastructure elements at Middle Warren
- Improve access into adjoining residential areas and develop cycle links into the proposed Hartlepool Rural Cycle route, including the western fringe of Hartlepool
- Investigate opportunities to naturalise Burn Valley Gardens beck
- Investigate opportunities for exploiting the geo-diversity value of Hart Quarry

5.4.1 Potential GI opportunities

Redevelopment and development of previously undeveloped land can provide GI opportunities. In already developed areas watercourses are often culverted to create space for development. By opening up culverted watercourses, flood risk can be reduced, the amenity value of the area can be improved and biodiversity can be increased. Undeveloped greenfield areas often have natural surface water flow pathways or watercourses running through them. The surface water flow pathways can be identified by the detailed surface water mapping completed for this study. When planning new development, these natural pathways should be kept open. Again, when the development is complete, these corridors will allow the watercourses and surface water to flood naturally, create an amenity focus for the site and improve biodiversity.

Locations where there may be GI opportunities in and around new developments, linking in the GI priorities/actions (listed above) are summarised in below. Within Hartlepool BC, there are a significant number of greenfield SHLAA sites outside of the main urban areas. In many cases, watercourses or smaller drains pass through these sites and then into the urban areas. Many of the GI opportunities involve keeping these watercourses open and even attenuating in the new development areas to prevent flood risk to new development and reduce downstream flood risk.

Table 5-1: Potential GI Opportunities

Proposed development site	GI opportunity
Wynyard North SHLAA site	Newton Hanzard Beck passes through the west corner of this site. This watercourse should be kept open and given space to flood. A detailed FRA should define the flood extent. This open watercourse could also add amenity and biodiversity value. The Billingham Beck Valley to Wynyard GI route runs parallel to this site. However, this does not appear to tie in with any surface water or watercourse flow routes.
Manor House Farm East SHLAA site	There is a strong surface water flow pathway here, which represents to flow path of a minor watercourse flowing into Cowbridge Beck. This should be kept open and given space to

Proposed development site	GI opportunity
	flood which also encourages amenity and biodiversity value. Although this watercourse does not have a Flood Zone, a detailed FRA should define the flood risk and extent here. This site also borders a GI route, but this does not tie in to any surface water/ fluvial flood risk areas.
Claxton Farm East and West and Ownton Grange Farm East and West SHLAA sites	A clear opportunity exists to tie in the GI route that runs alongside Greatham Creek with a future development plans here. This watercourse should be kept open (width defined by modelling in a FRA). This could form part of the Hartlepool Rural Cycle Route. Two smaller ditches convey surface water into this main watercourse. These should also be kept open so that they are allowed to flood and take surface water (at the original greenfield runoff rates). One of these surface water pathways flow through many of the SHLAA sites to the north, starting in Owton Grange Farm North and then alongside the existing development edge. This provides an opportunity for a long open green pathway.
Valley Drive and High Tunstall Farm	Burn Valley Beck and Tunstall Farm Beck pass through these SHLAA sites then converge. A smaller drain also passes through Valley Drive SHLAA site. Complex flood risk issues occur downstream of these watercourses. Flow should be reduced if possible. Some of these proposed development space could be used for flood flow attenuation and then open areas for the watercourses to flow through. The attenuation area could provide biodiversity and amenity value e.g. a reedbed system or a small lake. Although there are no GI routes here, these proposed open areas could form part of the Rural Cycle Route. This could also tie in with GI actions to naturalise parts of Burn Valley Back
Quarry Farm East and West SHLAA sites	Strong surface water flow path representing a small watercourse passing through the site. This contributes to the flood risk problem location mentioned above. This should be kept open so as to reduce flow and create other GI benefits.
Nelson Farm West and Hart Station	The surface water flow pathway shows the pathway of a small watercourse that runs through these sites. This should be kept open
Upper Warren Hart Reservoir	Keeping this watercourse open (indentified using the detailed surface water mapping) could tie in with the GI action to integrate GI elements of Middle Warren
Queens Meadow, Golden Flatts Brenda Road, South of Seaton Lane, Park View East	This entire development corridor follows the Stell watercourse. The decision was made to pull back from residential development in the areas that are potentially at risk of flooding from the Stell. If this area is developed in the future, opportunities exist to open up the Stell along the allocations listed here. This would reduce the strain on the drainage system here and promote other GI benefits. This could be a linear pathway (cycle route) from Greatham to Seaton Carew.

5.5 Future Studies

5.5.1 Surface Water Management Plan

Local authorities through the Lead Local Flood Authority (LLFA) are now required, under the Flood and Water Management Act (2010) and the Flood Risk Regulations (2009), to proactively manage surface water flood risk. To do this, LLFAs are required to develop a Surface Water Management Plan (SWMP).

Guidance for the SWMP promotes a risk based approach to flood management by initially assessing flood risk on a catchment scale and progressively focussing in on flood hotspots through completing assessments of increasing detail to understand the issues. The completed SWMP should provide an action plan of proposed further works for the LLFA to progress into the future.

The work undertaken as part of this Level 2 SFRA has gone a long way to completing the preliminary stages of the SWMP. The surface water mapping completed for this study provides a greater level of detail than is currently required for a strategic level assessment, the identification of CDAs will feed directly into the identification of flood hotspots for further assessment or the development of options and the consideration of green infrastructure provides an understanding of the way forward for managing overland flows.

The CDA section of this Level 2 SFRA leads directly to the upcoming SWMP. The confirmed CDAs should be used to focus the SWMP in order to get the most out of the funding available.

5.6 Surface Water Drainage and Development

When major proposed developments come forward, opportunities for developing a Drainage Management Strategy across site boundaries should be explored, and a catchment led approach should be adopted. This approach has been recognised in the consultation paper by Defra, Making Space for Water. An integrated approach to controlling surface water drainage can lead to a more efficient and reliable surface water management system as it enables a wider variety of potential flood mitigation options to be used. In addition to controlling flood risk, integrated management of surface water has potential benefits, including improved water quality and a reduction of water demand through grey water recycling.

Surface water drainage assessments are required where proposed development may be susceptible to flooding from surface water drainage systems. The potential impact upon areas downstream of the development, including the impact on a receiving watercourse, also needs careful consideration.

The specific requirements for surface water drainage systems will need to be discussed with the Council's Land Drainage Engineers, Environment Agency and Northumbrian Water. Consideration should be given to whether a "greenfield runoff approach" to the assessment of source control is appropriate. This method is generally satisfactory in the cases where the development is relatively small, isolated from other planned sites and the runoff processes are fully understood.

The FRA should then conclude with an assessment of the scale of the impact, and the recommended approach to controlling surface water discharge from a proposed development.

5.6.1 SUDS

This section provides a strategic summary of the applicability of SUDS techniques in Hartlepool BC. This is a broad scale assessment for strategic planning and should not be used for assessing individual sites. For more detailed assessments such as individual planning applications or site investigations, a comprehensive reporting service for specific locations can be found here: **http://www.landis.org.uk/services/sitereporter.cfm**

Table 5-3 shows the soil types, the expected ground conditions from this soil type and the SUDS techniques that will be possible with these ground conditions.

The SUDS techniques are categorised as storage (i.e. water stored on site and then slowly released) or infiltration (i.e. where surface water is allowed to infiltrate into the ground). Infiltration SUDS require ground conditions that allow the infiltration of surface water through the ground. Clay rich soils and areas with a high water table will not be suitable for infiltration SUDS. Table 5-2 shows the infiltration and storage SUDS techniques.

For this broad assessment, the soils data utilised is a simplified 1:250,000 soils dataset, derived from the more detailed National Soil Map. This is Cranfield University data and is available online. The drift geology data was obtained in GIS format from the British Geological Survey.

Table 5-2: Suitability of SUDS Techniques

SUDS Technique	Infiltration	Storage
Green Roofs	×	✓
Permeable Paving	✓	×
Rainwater Harvesting	×	✓
Swales	✓	✓
Detention Basins	✓	✓
Ponds	×	✓
Wetlands	×	✓
Source: PPS25 Practice Guide		

Table 5-3: Strategic SUDS Applicability

Area	Soils and drift	Ground conditions	SUDS Implications
North Tees industrial area (Graythorp, Tioxide, power station)	Drift - raised marine deposits (sand and gravel). Loamy and clayey soils of coastal flats with naturally high groundwater.	These soils are naturally wet and have naturally high groundwater levels.	SUDS infiltration techniques will not be possible, only SUDS storage techniques or underground storage basins.
Hartlepool coastal frontage (including Seaton Sands site)	Drift - raised marine deposits (sand and gravel). Sand dune soils.	This area has freely draining soils which means this area should absorb rainfall readily and allow it to drain through to underlying layers.	The soil type indicates that it should be suited to infiltration SUDS systems.
Manor House Farm development areas	Drift - clay. Loamy and clayey soils.	These soils have impeded drainage which means that they are generally wet and winter water logging can result in very wet ground conditions especially as the drift is clay.	SUDS infiltration techniques may not be possible, only SUDS storage techniques or underground storage basins.
Hart	Drift - till. Loamy and clayey soils	These soils have impeded drainage which means that they are generally wet and winter water logging can result in very wet ground conditions.	SUDS infiltration techniques may not be possible, only SUDS storage techniques or underground storage basins.
All other areas	Drift - till. Slowly permeable, seasonally wet loamy and clayey soils.	These soils have impeded drainage which means that they are generally wet and winter water logging can result in very wet ground conditions	SUDS infiltration techniques may not be possible, only SUDS storage techniques or underground storage basins.

6. Conclusions

6.1 Introduction

This Level 2 SFRA has built upon the work undertaken in the Level 1 SFRA update, completed in May 2010. The Level 1 SFRA identified areas where potential future development is at risk of flooding according to the Flood Zone maps, but a more detailed assessment of flooding is required to find the actual risk. As a result, the Level 2 Assessment has focussed on two areas, the tidal flood risk area around the north Tees Estuary and along Seaton Sands and the fluvial flood risk location at Hartlepool Hospital.

The Level 1 SFRA also identified candidate Critical Drainage Areas. These locations have been looked at in more detail in the Level 2 SFRA by undertaking detailed surface water mapping, collecting more data from and undertaking consultation with Hartlepool BC and Northumbrian Water and by undertaking a site visit.

6.2 Tidal Flood Risk

A 2D tidal model was produced for the area at risk of tidal flooding between the north Tees Estuary and Seaton Carew. Two scenarios were investigated, one was an undefended scenario, and the other represented the existing risk (with defences in place).

The undefended scenario shows that the current nuclear power station area, Century Park, Graythorp, Tofts Farm, Tees Road Seaton and Seaton Sands are not at risk from the 1 in 200 year undefended tidal event, whereas they are shown to be within the current Flood Zone 3. If this newly modelled 1 in 200 year flood extent is adopted by the Environment Agency and integrated into their flood maps, then it will become Flood Zone 3 and these sites will therefore not be within Flood Zone 3. However, the Tioxide and nuclear power station development areas are at risk from the undefended 1 in 200 year flood event so would remain in Flood Zone 3.

For the existing risk scenario, the sites are only flooded during the 1 in 200 plus climate change event. Of the sites being assessed only the Tioxide development area, proposed new nuclear power station area and Seaton Sands Development sites are shown to be at risk from this event.

After assessing the flood depth and hazard for the undefended and existing risk scenarios, it can be concluded that the proposed development sites can be safely developed with some mitigation measures and recommendations for a more detailed assessment at the flood risk assessment stage.

6.3 Fluvial Flood Risk

The Level 2 SFRA has investigated the fluvial flood risk to Hartlepool Hospital and Oakesway Industrial Estate indicated by the existing Flood Zone maps. The investigation has been based on available data and there is some uncertainty in the analysis but this is considered to be low.

The flooding mechanism to the site has been attributed to the trash screen at the Middle Warren Watercourse culvert inlet to the North Area Main Drain (NAMD).

With no debris build up on the trash screen there is sufficient capacity in this system to discharge the 1 in 100 year design event through the NAMD; the development sites would therefore not be at risk of flooding in this event in this scenario.

A significant build up of debris on the trash screen is currently more likely, at it is not unrealistic to assume the screen will be completely blocked in a large event. In this instance the development sites are at risk of flooding.

Flood risk to the development sites can be managed by robustly improving the capacity of the trash screen in flood events. A range of options, including maintenance or improvements to the trash screen, have been recommended for further investigation.

6.4 Critical Drainage Areas

The Level 2 SFRA has completed more detailed surface water mapping and consulted with HBC on the key flood risk areas.

Critical Drainage Areas (CDAs) have been identified and are as follows:

- Slake Watercourse
- Tunstall Beck - Valley Drive
- Tunstall Beck – Stranton (further work required before CDA can be confirmed)
- The Stell
- Oxford Road and Westbrooke Avenue
- Torquay Avenue to Benmore Lane
- Murray Street (look into formalising the overland flow routes)

It is recommended further investigations be completed as part of the detailed investigation or options appraisal phases in the upcoming Hartlepool BC Surface Water Management Plan (SWMP) to feed into the development of the action plan for Hartlepool.

Appendices

A. Figures

Provided separately

B. Glossary

Attenuation

Reduction of peak flow and increased duration of a flow event.

Catchment Flood Management Plans (CFMP)

A strategic planning tool through which the Environment Agency will seek to work with other key decision-makers within a river catchment to identify and agree policies for sustainable flood risk management.

Climate change

Long-term variations in global temperatures and weather patterns, both natural and as a result of human activity.

Compensation storage

A floodplain area introduced to compensate for the loss of storage as a result of land raising for development purposes.

Design event

A historic or notional flood event of a given annual flood probability, against which the suitability of a proposed development is assessed and mitigation measures, if any, are designed.

Design flood level

The maximum estimated water level during the design event.

DG5 register

Register held by water companies on the location of properties at risk of sewage related flooding problems

Digital Elevation Model (DEM)

A digital representation of ground surface topography or terrain. It is also widely known as a digital terrain model (DTM).

Extreme Flood Outline

Flood 'zone' maps released by the Environment Agency to depict anticipated 0.1% (1 in 1000 year) flood extents in a consistent manner throughout the UK

Flood defence

Flood defence infrastructure, such as flood walls and embankments, intended to protect an area against flooding to a specified standard of protection.

Flood Map

A map produced by the Environment Agency providing an indication of the likelihood of flooding within all areas of England and Wales, assuming there are no flood defences. Only covers river and sea flooding.

Floodplain

Area of land that borders a watercourse, an estuary or the sea, over which water flows in time of flood, or would flow but for the presence of flood defences where they exist.

Flood Risk Management (FRM)

The introduction of mitigation measures (or options) to reduce the risk posed to property and life as a result of flooding. It is not just the application of physical flood defence measures.

Flood risk management strategy

A long-term approach setting out the objectives and options for managing flood risk, taking into account a broad range of technical, social, environmental and economic issues.

Flood Risk Assessment (FRA)

A study to assess the risk to an area or site from flooding, now and in the future, and to assess the impact that any changes or development on the site or area will have on flood risk to the site and elsewhere. It may also identify, particularly at more local levels, how to manage those changes to ensure that flood risk is not increased. PPS25 differentiates between regional, sub-regional/strategic and site- specific flood risk assessments.

Flood risk management measure

Any measure which reduces flood risk such as flood defences.

Flood Zone

A geographic area within which the flood risk is in a particular range, as defined within PPS25.

Fluvial

Flooding caused by overtopping of rivers or stream banks.

Freeboard

The difference between the flood defence level and the design flood level, which includes a safety margin for residual uncertainties.

Greenfield land

Land that has not been previously developed.

ISIS

ISIS is a software package used for 1-Dimensional river modelling. It is used as an analysis tool for flood risk mapping, flood forecasting and other aspects of flood risk management analysis.

LIDAR

Light Detection And Ranging. Airborne laser mapping technique producing precise elevation data (see DEM).

Local Development Framework (LDF)

A non-statutory term used to describe a folder of documents which includes all the local planning authority's Local Development Documents (LDDs). The local development framework will also comprise the statement of community involvement, the local development scheme and the annual monitoring report.

Local Development Documents (LDD)

All development plan documents which will form part of the statutory (LDDs) development plan, as well as supplementary planning documents which do not form part of the statutory development plan.

Main River

A watercourse designated on a statutory map of Main Rivers, maintained by Defra, on which the Environment Agency has permissive powers to construct and maintain flood defences.

Major development

A major development is:

a) where the number of dwellings to be provided is ten or more, or the site area is 0.5 Ha or more or

b) non-residential development, where the floor space to be provided is 1,000 m^2 or more, or the site area is 1 ha or more.

NFCDD

The Environment Agency's National Flood and Coastal Defence Database (NFCDD).

Ordinary watercourse

All rivers, streams, ditches, drains, cuts, dykes, sluices, sewers (other than public sewer) and passages through which water flows which do not form part of a Main River. Local authorities and, where relevant, Internal Drainage Boards have similar permissive powers on ordinary watercourses, as the Environment Agency has on Main Rivers.

Permitted development rights

Qualified rights to carry out certain limited forms of development without the need to make an application for planning permission, as granted under the terms of the Town and Country Planning (General Permitted Development) Order 1995.

Planning Policy Statement (PPS)

A statement of policy issued by central Government to replace Planning Policy Guidance notes.

Previously-developed land

Land which is or was occupied by a permanent structure, including the (often referred to brownfield land) curtilage of the developed land and any associated fixed surface infrastructure (PPS3 annex B)

Ramsar Site

Sites identified or meeting criteria set out in The RAMSAR Convention on Wetlands of International Importance. This definition has no legal status, but such sites are designated as SSSIs under the Wildlife and Countryside Act 1981 (as amended).

Reservoir (large raised)

A reservoir that holds at least 25,000 cubic metres of water above natural ground level, as defined by the Reservoirs Act, 1975.

Residual risk

The risk which remains after all risk avoidance, reduction and mitigation measures have been implemented.

Resilience

Constructing the building in such a way that although flood water may enter the building, its impact is minimised, structural integrity is maintained and repair, drying & cleaning are facilitated.

Resistance

Constructing a building in such a way as to prevent flood water entering the building or damaging its fabric. This has the same meaning as flood proof.

Return period

The long-term average period between events of a given magnitude which have the same annual exceedence probability of occurring.

Risk

The threat to property and life as a result of flooding, expressed as a function of probability (that an event will occur) and consequence (as a result of the event occurring).

Run-off

The flow of water from an area caused by rainfall.

Shoreline Management Plan (SMP)

A plan providing a large-scale assessment of the risk to people and to the developed, historic and natural environment associated with coastal processes. It presents a policy framework to manage these risks in a sustainable manner.

Standard of Protection (SOP)

The design event or standard to which a building, asset or area is protected against flooding, generally expressed as an annual exceedence probability.

Strategic Flood Risk Assessment (SFRA)

The assessment of flood risk on a catchment-wide basis for proposed development in a District.

Sustainable Drainage Systems (SUDS)

A sequence of management practices and control structures, often referred to as SUDS, designed to drain water in a more sustainable manner than some conventional techniques. Typically these are used to attenuate run-off from development sites.

Sustainability Appraisal (SA)

An integral part of the plan-making process which seeks to appraise the economic, social and environmental effects of a plan in order to inform decision-making that aligns with sustainable development principles.

TUFLOW

TUFLOW is a software package used for 2-Dimensional river modelling. It is used as an analysis tool for flood risk management analysis.

Vulnerability Classes

PPS25 provides a vulnerability classification to assess which uses of land maybe appropriate in each flood risk zone.

Washland

An area of the floodplain that is allowed to flood or is deliberately flooded by a river or stream for flood management purposes.

Water Framework Directive (WFD)

A European Community Directive (2000/60/EC) of the European Parliament and Council designed to integrate the way water bodies are managed across Europe. It requires all inland and coastal waters to reach “good status” by 2015 through a catchment-based system of River Basin Management Plans, incorporating a programme of measures to improve the status of all natural water bodies.

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