SCARBOROUGH BOROUGH COUNCIL

Burniston, Cloughton & Quarry Becks

Flood Alleviation Scheme – Phase 2

Final including Client comments

Notice

This document has been produced by ATKINS for Scarborough Borough Council solely for the purpose of the Burniston, Cloughton & Quarry Becks project appraisal report.

It may not be used by any person for any other purpose other than that specified without the express written permission of ATKINS. Any liability arising out of use by a third party of this document for purposes not wholly connected with the above shall be the responsibility of that party who shall indemnify ATKINS against all claims costs damages and losses arising out of such use.

Document History

JOB NUMBER: 5002531			DOCUMENT REF: 5002531/88/DG/67			
Revision	Purpose and Description	Originated	Checked	Reviewed	Authorised	Date
D-1	Draft for Internal Review	J Fisher	O Drieu	T Ishaq	T Ishaq	June 04
D-2	Draft for Client Comment	J Fisher	O Drieu	T Ishaq	T Ishaq	July 04
D-3						

CONTENTS

Glossary of terms 4

Executive Summary 1

Consideration of risks 2

Recommendations .... **Error! Bookmark not defined.**

1 Introduction 4

1.1 Background 4

1.2 General Description of the Watercourses 4

1.3 Report Structure 4

2 Flooding History 5

3 Previous Reports and Data Available 6

3.1 Previous Reports 6

3.2 Topographic Survey 6

3.3 Other Data Obtained 6

3.4 List of References Used 7

4 Ecological Assessment of Cloughton & Burniston Watercourses 8

4.1 Introduction 8

4.2 Morphology 8

4.3 Flora And Fauna (General) 9

4.4 Protected Species 9

4.5 Invasive Species 10

4.6 Mitigation and/or Enhancements 10

4.7 Introduction 11

4.8 Morphology 11

4.9 Flora And Fauna (General) 11

4.10 Protected Species 12

4.11 Invasive Species 13

4.12 Mitigation and/or Enhancements 14

5 Hydrological Modelling 15

5.1 Catchment Definition 15

5.2 FEH Methodology 15

5.3 Rational Method 17

5.4 Design Flows - Discussion 17

6 Hydraulic Modelling 19

6.1 General 19

6.2 Flooding Flow Routes 19

6.3 Schematisation of the River System 19

6.4 Boundary Conditions 21

6.5 Model Verification 21

6.6 Sensitivity Analysis 22

6.7 Flood Extents 23

7 Discussion of Measures to Mitigate Flooding 24

7.1 Measure 1 – Flood Flow Retention Storage 24

7.2 Measure 2 - Localised Defences 24

7.3 Measure 3 - Improvements to Structures 25

7.4 Measure 4 – Channel Widening 26

7.5 Measure 5 – Temporary Defences 26

8 Description of Flood Mitigation Options 27

8.1 Option 1 - Do Nothing 27

8.2 Option 2 - Do Minimum 27

8.3 Option 3 – Localised Defences, Improvements to Structures and Channel Widening 27

8.4 Option 4 – Localised Defences, Improvements to Structures, Channel Widening and Raising Caravan Floor Levels 28

9 Economic Appraisal Methodology 29

9.1 Objectives 29

9.2 Estimation of Flooding Depths 29

9.3 Depth Damage Data 29

9.4 Write-off Values 29

9.5 Options Analysed 30

10 Assessment of Benefits 31
10.1 'Do Nothing' Damages 31
10.2 'Do Minimum' Damages 33
10.3 Assessment of Option 3 33
10.4 Option 4 35
10.5 Present Value Damages 37
10.6 Loss of Life 37
10.7 Traffic Disruption 37
10.8 Assessment of Risks 37
11 Assessment of Costs 39
12 Benefit Cost Analysis 40
13 Conclusions & Recommendations 42
13.1 Flooding causes, extents and mechanisms 42
13.2 Preferred flood mitigation option 42
13.3 Consideration of risks 43
13.4 Recommendations 43

Appendix A: Figures
Appendix B: Photographic Record
Appendix C: Hydrological Analysis
Appendix D: Depth of Flooding
Appendix E: Benefit Analyses
Appendix F: Cost Appraisal
Appendix G: Benefit Cost Appraisal
Appendix H: Ecological Assessment Report

Glossary of terms

Term	***Meaning / Definition***
AAD	Average Annual Damages
AOD	Above Ordnance Datum
BF	Base Flow (an FEH term)
Defra	Department For Environment, Food and Rural Affairs (formerly MAFF)
EA	Environment Agency
FAS	Flood Alleviation Scheme
FEH	Flood Estimation Handbook
FSR	Flood Studies Report
ISIS	Mathematical one-dimensional hydrodynamic model for open channel flow
LiDAR	Light Detection And Ranging (ground levels from aerial survey)
MAFF	Ministry of Agriculture, Fisheries and Food (now Defra)
MCM	Multicoloured Manual (for deriving costs of flooding)
NPV	Net Present Value
PAG3	Project Appraisal Guidance Volume 3
PAR	Project Appraisal Report
Phase 1 Report	Critical Watercourse Study – Burniston Beck, (Atkins July 2002)
PR	Percentage Runoff
PV	Present Value
Q100	1 in 100 year return period
Q_{MED}	(Q 'med') Median Annual Flood
RPI	Retail Price Index
SAAR	Standard Annual Average Rainfall (an FEH term)
SBC	Scarborough Borough Council
SoP	Standard of Protection
T_P	Time to peak (an FEH term)
URBEXT	Urban Extent (an FEH term)
WINFAP-FEH	FEH Windows software package

Executive Summary

A phase 1 (scoping report) on the flooding issues was undertaken in 2002 for Burniston Beck. During this study a flood event occurred in August 2002 that affected several properties outside the original study reach. At that stage it was determined that a more detailed options phase 2 study was justified.

For this current assessment the study reach has been extended to include Cloughton Beck, Quarry Beck and Burniston Beck, to the confluence with Sea Cut (Burniston Beck changes its name to Cow Wath from Cow Wath Bridge to the confluence with Sea Cut). This, current report represents a detailed mathematical modelling exercise that has been undertaken to determine the causes, extents and frequency of flooding. Mitigation options have also been assessed and costed.

Consideration of risks

Flooding to properties around the West Lane area of Cloughton Beck and the Bridge Close area of Burniston Beck is frequent, therefore justifying their designation as Critical Ordinary Watercourses. The most recent severe flood occurred in August 2002 when flooding was experienced at a number of locations in the catchment. These areas included the West Lane area, Becks Lane, Bridge Close and the caravan park.

Hydrological assessments have determined that the peak flow for the entire Burniston Beck catchment is $19m^3/s$, with the sub-catchments of Cloughton and Quarry Beck being $3m^3/s$ and $16m^3/s$ respectively for the 1 in 100 year event. For the 1 in 50 year event the peak flow for Burniston is $17m^3/s$.

Hydraulic modelling predicts that flooding is first experienced by 8 properties in the West Lane area at a return period of 1 in 10 years. The flooding is a result of culvert incapacity under West Lane. This rises to 63 properties for the 50 year event and 69 properties for 100 year event. Flood depths of up to 600mm are predicted for some properties for the 1 in 100 year event.

Specific Causes of Flooding

The hydraulic analyses have revealed that there are a number of contributing factors to flooding in the area caused by various mechanisms. The table below summarises the causes, extents and locations of the flooding and these are described in more detail in subsequent paragraphs.

Location	No. of Properties affected (100 yr event)	Causes	Return Period for Start of flooding
West Lane Culvert	27	Incapacity of culvert	10 years
Becks Lane	19	Incapacity of channel	50 years
Rocks Lane Bridge	14	Upstream incapacity of channel and bridge Downstream incapacity of channel and Bridge Close Bridge	U/S 100 years D/S 50 years
Bridge Close Bridge	9	Incapacity of bridge and channel	25 years
Caravan Park	N/A	Incapacity of channel	25 years

The capacity of key structures is the direct cause of flooding at a number of locations. The culvert under West Lane is undersized and causes backing up of the flow, which spills across West Lane flooding properties on West Lane and Little Moor Close. The Bridge at Bridge Close causes backing up and the low right bank causes floodwaters to bypass the bridge, flooding properties on Bridge

Close and Willymath Bridge (Coastal Rd). The incapacity of Rocks Lane Bridge in combination with the incapacity of the river channel causes the floodwaters to reach such a level that flooding of properties upstream of bridge is observed.

In the Beck Lane area flooding is caused by the lack of capacity in the river channel, therefore causing floodwater to flow over land and flood properties along Beck Lane and Church Beck cottages. Due to the natural topography in the caravan park area once the channel capacity has been reached the only route for the floodwater to take is in to the caravan park area.

Mitigation Measures Proposed

Some of mitigation measures, such as flood storage, were dismissed as there were no suitable areas available for flood storage before costing. However, a number of mitigation measures were assessed tested and costed as summarised in the table below. (Options 1 and 2 represent do nothing and do minimum but have been rejected.) A range of return periods were also assessed and the 50 year standard of protection was considered to be the most cost-beneficial for the preferred scheme.

Summary of mitigation measures and cost benefit assessment.

<table>
<tr><th></th><th>Option 3</th><th>Option 4</th></tr>
<tr><td>Protecting properties West Lane and Little Moor Driver Area</td><td colspan="2">Improve West Lane culvert to a box culvert 1 m by 1.2m</td></tr>
<tr><td>Protecting Properties Church Beck Cottages and Beck Lane Area</td><td colspan="2">Construction a flood embankment average height 750mm for 500m</td></tr>
<tr><td>Protecting properties Rocks Lane and Bridge Close</td><td colspan="2">(i) Embankment downstream Rocks Lane Bridge average height 400mm, right bank 150m and left bank 75m
(ii) Floodwall upstream of Bridge Close average height 850mm for 60m</td></tr>
<tr><td>Protecting Caravan Park</td><td>Flood embankment average height 750mm for 450m</td><td>Raise Caravans above 1 in 50 year flood event</td></tr>
<tr><td>Maintenance Measures</td><td colspan="2">(i) The structures are frequently inspected for debris and any trash screens cleaned along the watercourses. These should also be designed to be accessed and cleaned during flood conditions.
(ii) The channel vegetation and debris is required to be kept ‘under control’ to assist in maximising the channel capacity.</td></tr>
<tr><td>Cost Benefit Ratio
(50 yr SoP)</td><td>2.5</td><td>3.5</td></tr>
<tr><td>Defra Priority Scores
(50 yr SoP)</td><td>12</td><td>16</td></tr>
</table>

Ecological consideration

The main ecological risks are associated with the presence of otters along Burniston Beck and the possible presence of badgers and bats. Licences, and close consultations with Defra and English Nature will be required for the development of any proposals.

Selection of Proposed Scheme

The cost difference between option 3 and 4 is due to the proposed construction of a bund to protect the caravan park or raising the floor level of the caravans to stop internal flooding. This is reflected in the benefit cost ratio. Therefore the cost benefit ratios, a consideration of risks associated with the schemes and the Defra priority score have been considered in order to make a decision on the preferred option.

In conclusion, option 4 is the preferred scheme based on the low costs, higher cost benefit ratio and favourable Defra priority score. The risk and ecological benefits are similar for each of the options. This scheme designs flooding out of the system by several localised flood defence structures, replacement of the West Lane culvert and channel widening downstream of the culvert. It is recommended that a 200 year standard of protection is adopted throughout this scheme.

Recommendations

(i) Burniston and Cloughton Becks are considered to be critical ordinary watercourses and this status should be maintained.

(ii) In terms of the selection of freeboard and factors of safety regarding channel design, a manning's n of 0.08 (to simulate a highly vegetated channel) increased water levels of 100-200mm for the 100 year design event. It is recommended that this robustness should be accommodated for in the design as freeboard and a minimum 300mm should be allowed for.

(iii) This Phase 2 Report has revealed that there is a strong economic case to advance this project and present it to Defra for grant aid assistance with a benefit cost ratio of 3.5.

(iv) As part of the detailed design phase, a comprehensive site investigation would be required. This will consist of a full services search, and relevant boreholes to determine ground conditions. This will enable a greater level of confidence to be placed in the scheme costs which could then be revisited. The issue of permission to do works on land will also need to be further investigated.

(v) The progression of this study will need to incorporate a carefully designed consultation strategy to ensure that all stakeholder comments, aspirations and opportunities are maximised.

(vi) It is recommended that consideration be given to local rainfall and water level monitoring such that a calibration of the hydraulic model can be undertaken at a future date. However, it is not suggested that the project is delayed for this requirement.

(vii) It is recommended that the area be flown to obtain LiDAR data. This will help improve the accuracy of the flood outlines.

1 Introduction

1.1 Background

Atkins Consultants Limited (Atkins) was commissioned by Scarborough Borough Council (SBC) to prepare a project appraisal report (PAR) for Burniston, Cloughton and Quarry Becks critical ordinary watercourses. The aim of this report is to assess and justify the implementation of a flood alleviation scheme (FAS) for the area. It is intended that this report would be submitted to Defra for grant aid on capital expenditure.

This report represents phase 2 of the Burniston/Cloughton project. Phase 1 consisted of a preliminary assessment of the flooding problem using a limited ground survey, a hydrological assessment, the collation and population of a flood history table and the initial costings and economic appraisal of potential solutions. The Phase 1 report concluded (Atkins, July 2002) that the project was economically and technically viable to proceed towards a more detailed modelling and option assessment stage.

1.2 General Description of the Watercourses

The villages of Cloughton and Burniston are situated a few miles to the north of Scarborough. Cloughton and Quarry Becks are tributaries of Burniston Beck with the confluence upstream of A171 Bridge in Burniston. At this point there is an old Mill Race which is fed by Burniston Beck. The Mill Race rejoins Burniston Beck upstream of the community centre. Burniston Beck continues to flow in a Southerly direction until its confluence with Sea Cut, where Burniston Beck is called Cow Wath. A general location plan is shown in Appendix A.1 and a detailed description of the catchment is presented in Section 4.1.

Flooding has occurred on two occasions recently in October/November 2000 and August 2002. The areas affected by flooding are presented in Appendix A.2.

1.3 Report Structure

This report outlines the work undertaken as part of this study. This includes a summary of:

- An ecological survey and an assessment of the impact of the preferred option on the ecology and environment.
- The hydrological modelling of Burniston, Cloughton and Quarry Becks.
- The hydraulic modelling of the watercourses.
- The proposal of options for a FAS.
- An economic assessment.
- Full details of the recommended option for a FAS.

2 Flooding History

Following discussions with long-term residents of the area and data collected, five recent flooding events from the watercourses were identified. These occurred in June 2000, November 2000, August 2002, October 2002 and most recently January 2003. Of these events the August 2002 was the most serve and details of the numbers and locations of properties affected during this event are summarised in Table 2.1. Reports of flooding to farmland and gardens have been received prior to the 2000 events although this does not imply that no internal flooding of properties occurred before this date.

Table 2.1 – August 2002 Flood Event

<table>
<tr><th>Area</th><th>No. of Properties Affected (internal and external)</th></tr>
<tr><td>Burnside & Scalby Close Caravan Parks</td><td>Insufficient channel capacity caused flooding around the footbridge and adjacent land. Approximately 80 caravans were affected and floodwater depth of 4 feet observed.</td></tr>
<tr><td rowspan="2">Bridge Close</td><td>Insufficient channel capacity, channel blockages and bridge afflux caused flooding.</td></tr>
<tr><td>8 properties on Bridge Close and Coastal Road flooded internally
4 properties on Rocks Lane flooded externally including solum</td></tr>
<tr><td>Overgreen Close</td><td>Insufficient channel capacity. 2 residential gardens flooded.</td></tr>
<tr><td rowspan="2">Beck Lane</td><td>Insufficient channel capacity and surface runoff</td></tr>
<tr><td>6 properties on Beck Lane flooded internally
11 sheltered accommodation bungalows flooded externally</td></tr>
<tr><td>Little Moor Drive & West Lane</td><td>Insufficient culvert capacity under West Lane caused overland flows
3 properties flooded internally
5 residential gardens flooded</td></tr>
</table>

(Note: 'solum' represents average ground level and indicates that flood water would affect property foundations without any actual internal flooding. The EA defines a property as being flooded when water levels reach 150mm below ground floor level)

Three sources of flooding have been identified in the table above, namely:

1) Culvert under West Lane – insufficient capacity.

2) Blockages in the channel – debris, vandalism.

3) Overgrown channel – increasing roughness and contributing to debris during storm events.

These sources are shown on Appendix A.2. Photographs of the October 2000 flooding event and resident questionnaires can be found in the Phase 1 report and have not been reproduced in this report.

3 Previous Reports and Data Available

3.1 Previous Reports

The Environment Agency has completed a Section 105 Study for Burniston Beck and Quarry Beck. The study reach extended a downstream boundary of Rocks Lane Bridge to an upstream limit of *** on Quarry Beck. No study was completed for Cloughton Beck. There has also been a Phase 1 report, for the Burniston Beck flooding situation.

3.2 Topographic Survey

Survey Operations Limited was commissioned to provide topographic survey data for Burniston, Cloughton and Quarry Becks. This included:

- threshold and road levels through parts of Burniston affected by flooding;
- spot levels and contours for
  - Cloughton Cricket Field
  - The confluence of Cloughton, Quarry and Burniston Becks
  - The fields opposite Church Beck Cottages, Cloughton
  - Stone Quarry Road Bridge area (Quarry Beck)
  - The Caravan Park (Burniston Beck)
- cross sections through the open watercourses,
- culvert inlet and outlet units and upstream and downstream sections of bridges including deck levels.
- photographs of the channel and structures (see Appendix B)

There was LiDAR data available for the area surrounding Sea Cut. This however only extends from the confluence with Sea Cut to an upstream limit by the caravan park (502 087, 491769). The LiDAR data was collected in 2003 and the heights were checked against the topographical survey at key locations. There appeared to be a discrepancy between the heights from the two sources of data, which was not consistent throughout the whole study area. A greater confidence was placed on the accuracy of the topographical survey and the LiDAR data was used with caution.

3.3 Other Data Obtained

In addition to the above, the following information was obtained and reviewed as part of this study:

- various newspaper cuttings reporting on historical flooding events;
- photos provided by residents following the floods;
- site visits were undertaken to assess the various flooding mechanisms and flood mitigation options.

3.4 List of References Used

A list of the references used in this study is given below:

- *FCDPAG3 Economic Appraisal Supplementary Note to Operating Authorities - Revisions to Economic Appraisal Procedures Arising from the new HM Treasury "Green Book"*, Defra, March 2003.

- *The Benefits of Flood and Coastal Defence: Techniques and Data for 2003 (the Multi-Coloured Manual)*, Middlesex University and the Flood Hazard Research Centre, January 2003.

- *Flood Estimation Handbook – Procedures for Flood Frequency Estimation*, Duncan Reed, Institute of Hydrology, 1999.

- *Critical Watercourse Study, Burniston Beck, Atkins, January 2003 (the Phase 1 report)*

4 Ecological Assessment of Cloughton & Burniston Watercourses

Atkins have produced a separate, full ecological report for a number of watercourse in Scarborough, namely, Church Beck, Long Plantation Watercourse and Burniston and Cloughton Becks. A summary of the relevant findings to this study are presented in the following sections.

Cloughton Watercourse

4.1 Introduction

Cloughton Beck is to the west of Cloughton Village and is a small watercourse sourced from a slack on Little Moor. Cloughton Beck converges with Quarry Beck in the west before becoming Burniston Beck at the confluence near Cloughton Bridge.

Cloughton Beck (arising on Little Moor) is a narrow watercourse that flows in a southerly direction. On the upper reaches, the beck retains a natural profile running through a mosaic of woodland, bracken (Pteridium aquilinum) scrub and semi-improved grassland. The beck enters a culvert at White Way/ West Lane and upon exit the channel has been modified to a narrow profile with retaining walls on either side. This stretch of the beck passes through the grounds of residential properties of Little Moor Close.

South of the close, the channel is less modified and delineates the end of land belonging to properties to the east (left bank) including a public house and other buildings. On the western side (right bank) the land use is more open with a cricket pitch and poor semi-improved grassland used for livestock grazing. This land backs onto an area known as Goose Dale and Quarry Banks.

Together Goose Dale and Quarry Banks are notified as a non-statutory Site of Importance for Nature Conservation (SINC). This area is important for its hillside mosaic of calcifuge vegetation, including communities of plantation woodland, gorse (Ulex europaeus), and poor semi-improved acid grassland. To the south of Quarry Banks a small water course (Lindhead and then Quarry Beck) runs easterly through a predominately rural landscape before converging with Cloughton Beck to become Burniston Beck.

4.2 Morphology

The beck retains a natural form throughout the upstream reaches, the channel is generally narrow (1.5m max) and contained within a steep-sided gorge approximately 3-4m high and about 7m wide. This profile is varied with bank height and angle fluctuating depending on the geology and surrounding woodland. The substrate is rocky with little sand and silt, the flow rate at the time of survey was moderate but became sluggish further downstream.

The beck is culverted under West Lane/White Way where a grille is located to collect litter and debris. At the time of the survey this was blocked with branches and leaf litter allowing only a low flow to enter. (See Target Note 2 / Map1).

A small section of beck to the east of Cloughton Beck also enters the culvert at West Lane/ White Way. This section contained stagnant water with no in–channel vegetation and was generally overgrown by a bordering hedge. (See Target Note 14/ Map1)

The beck exits the culvert at Little Moor Close where it becomes a very narrow walled channel of approximately 0.5m wide and 1m high. The flow at this point was sluggish with clean water of only 0.1m deep. (Target note 3/ Map1). Upon exit, behind Little Moor Close, Cloughton Beck widens out to approximately 1m, however the channel is still heavily modified. The cobbles and increasing amount of silt in the substrate has allowed a more diverse macropyhte composition to establish along this reach and the occasionally walled and banked sides have also been colonised with some marginal vegetation. (Target note 4/Map1) This profile continues along the length of the reach until converging with Quarry Beck to become Burniston Beck. The beck is forded at Moor Lane where it is carried by 15cm twin pipe culverts across the road. (Target Note 5/Map2)

4.3 Flora and Fauna (General)

Upstream (above White Way/West Lane)

There is little in-stream or marginal vegetation along the upstream reaches of Cloughton Beck. Floral interest throughout this area comprises fern and lower plant assemblages amongst the gorge and the woodland vegetation along the gorge edges. (Further survey of this area is recommended during the optimum period in spring to record vernal plants if this section is to be affected by the alleviation scheme)

There was some evidence of badger activity (See Target note 8/Map 1) with mammal paths extending through a thicket of blackthorn (Prunus spinosa) scrub. Roe deer were also recorded using the upstream areas of woodland and poor semi-improved grassland. A fatality was recorded on the barbed wire fence at Target Note 9/Map2.

Downstream (below White Way/West Lane up to Burniston Beck)

On the downstream reaches of the beck there is increasing macrophyte interest, (flora is given by target note at each relevant location) and may increase the diversity of invertebrates along the lower course of the beck. The downstream reaches had active badger field signs with paths, recent dung pits and foraging scrapes.

There was local anecdotal evidence of brown trout and water vole along this reach, however, no evidence of these species was recorded during the survey. Consultation with English Nature has indicated records of otters downstream on Cloughton Beck.

4.4 Protected Species

Water vole

Generally the upstream reaches of Cloughton Beck provide little suitable habitat for water voles. However, the species is known to exploit various habitats and are occasionally recorded in atypical environments. The habitat is generally shaded by woodland with little burrowing substrate, although one large swathe of soft rush and grasses on the left bank may provide suitable forage and nesting material for the species.

The lower reaches display habitat more suitable for water vole colonisation and anecdotal evidence suggested the presence of the species. However, no field evidence such as burrows, latrines, feeding stations or lawns were observed during the survey.

It should be noted that the baseline survey was undertaken at a sub-optimal time, water vole surveys should generally be undertaken during the period from late-April to early October with May, June and July as the optimal time of finding breeding territories marked by latrines.

It is likely that water voles are present on Cloughton Beck and a detailed survey should be undertaken at the next stage.

Great crested newt

There are no potential breeding ponds within the area and habitat to support the species is minimal it is therefore unlikely that the species will be affected by flood alleviation on the watercourse.

Badger

There was a large amount of badger activity recorded along the corridor of the beck. Evidence ranged from fresh dung pits and foraging scrapes to obvious mammal pathways. (These field signs have been recorded as Target notes). However, badger setts were not observed during the survey.

Badgers are protected under the Protection of Badgers Act 1992 which consolidates other legislation and creates the offence of intentionally or recklessly interfering, damaging or destroying a sett or disturbing an occupied sett. It is unlikely that the scheme will directly impact upon individuals or their setts, however there may be disturbance of setts through construction that may require a licence from Defra, this will depend on the proximity of an active sett to the works and the methods employed for the flood alleviation scheme.

White clawed crayfish

There is limited potential for white-clawed crayfish on Cloughton Beck. The calcifuge vegetation recorded in this survey indicates more acidic soil chemistry and may be derived from the local geology. Therefore, the waters are likely to also be acidic and unable to support the species. However the precautionary approach should be employed and the water pH and local species records should be checked.

Otter

The upstream reaches display little interest for otters, although occasional presence may be attributed to dispersal of juveniles. Consultation with English Nature has indicated that the downstream section of Cloughton Beck may be used by the species. Further downstream, the beck provides more suitable habitat with adjacent woodland and scrub providing less disturbed resting-up sites. The confluences with Quarry Beck and Burniston Beck provide suitable habitat with a deeper pool near the weir (Target Note 2/Map2).There is also ample cover and potential for the beck to support the quantities of fish necessary to support otters in a forage or dispersal capacity. Further survey and consultation will be required with regard to otters.

A licence may be required from Defra in respect of disturbing a European protected species should works affect areas known to be used by otter as resting sites, holts, hovers etc.

4.5 Invasive Species

No invasive species were recorded on Cloughton Beck.

4.6 Mitigation and/or Enhancements

The course of the beck retains some natural sinuosity and this should not be altered by potential flood alleviation schemes. Changes to the channel and flow rates may have implications for the entire downstream reach including Burniston Beck and Sea Cut. The presence of protected species, (badger, otter and water vole) may constitute a considerable constraint to works.

The close proximity to Goose Dale and Quarry Banks SINC should be considered carefully, especially with regard to the placement of potential flood storage areas. There should be no piping of the channel and culverts should be used only where absolutely necessary. The alleviation design should be sensitive to the environmental impacts on the entire catchment and maintain the continuity of these watercourses. Mitigation should be designed to offset any residual impacts incurred through the scheme.

The following mitigation should be considered:

- flood storage area designed to enhance the existing nature conservation interest and contribute towards local biodiversity targets. Pasture land adjacent to the cricket pitch could be used for this purpose however the design should be tailored to compliment the natural area, the characteristics associated with the SINC and existing marginal flora;
- improve the ford crossing at Moor/Beck Lane to allow fish passage;
- the creation of wildlife ledges in culverts (where and if applicable), and under bridges (both new and existing structures) to allow the passage of riparian mammals and badgers.

The following constraints are likely given the information available at this stage:

- impacts to Goose Dale and Quarry Banks SINC;
- presence of badger (no setts located at this stage);
- possible presence of legally protected species: otter and water vole;
- the retention of the channel's existing form: no piping should be undertaken.

The following measures are suggested:

- a bat survey should be undertaken should the scheme be anticipated to involve the removal of trees;
- detailed flora survey;
- consultation and otter surveys;
- consultation and water vole surveys;
- consultation and badger surveys;
- survey and consultation regarding local fisheries;
- full survey of Quarry Beck;
- survey of section between weir (Target note 2/ Map 2) and Burniston Beck confluence (Target note 5/ Map 2);
- a detailed River Corridor Survey (RCS) along the entire reach;
- close liaison with Yorkshire Wildlife Trust with regard to the design and implementation of flood alleviation measures, should these be undertaken.

BURNISTON BECK

4.7 Introduction

Burniston Beck (or Cow Wath Beck) originates from the confluence of Cloughton Beck and Quarry Beck. It runs in a southerly direction to the east side of Burniston village through a mixture of arable farmland and semi-improved grassland and into Sea Cut at Scalby (also known as Scalby Beck at this location).

4.8 Morphology

The channel is wider and deeper than Cloughton Beck, there is little in-stream vegetation and the substrate becomes progressively silty along the upstream reach. Further downstream, larger boulders become frequent and bank vegetation is more natural and diverse after crossing Station Road. Here the beck flows down through a gorge to reach the confluence with Sea Cut and the natural form and vegetation make the channel a feature of high conservation value.

The profile between Rocks Lane and Willymath Bridge is on average between 2-3m wide, with a water depth of 0.25-0.5m. Downstream of this point the width increases to between 3 and 4 m, whilst maintaining shallow water levels and a sluggish flow rate.

4.9 Flora and Fauna (General)

There is generally little in-stream vegetation with occasional brooklime, branched bur-reed and soft rush present on the margins. The downstream reaches have scrub margins with osier (Salix viminalis), gorse and goat willow (Salix caprea) dominant amongst alder and larger specimens of crack willow. This scrub provides niches for a variety of wildlife and represents significant nature conservation value.

Faunal interest is anticipated to be quite diverse, otter was confirmed along the reach and water vole, invertebrate and fisheries interest are likely.

4.10 Protected Species

Water vole

There were no sightings or field evidence of water voles during the survey. However, it is likely that the species is present where the bank permits burrowing and bankside vegetation provides forage. A thorough survey is recommended along reaches that will be affected by flood alleviation proposals.

Great crested newt

It is unlikely that great crested newts will be present along the corridor as there were no recorded pools within a 500m proximity to the Burniston Beck.

Badger

It is likely that badgers use this corridor as a foraging pathway. Setts may be present in vegetation immediately adjacent to the beck at the confluence with Sea Cut.

White clawed crayfish

There is limited potential for white-clawed crayfish on Burniston Beck although (as for Cloughton Beck) pH and local records should be checked.

Otter

English Nature has provided consultative information of otters on Burniston Beck. The survey also gained anecdotal evidence of otter activity from a local landowner. Assessment of the riparian habitat indicated a high potential of supporting otters with areas of seclusion, some holt availability, laying up sites and available prey.

The survey recorded one otter spraint at a single location along the course of the beck. The spraint was recent (within 1 week) and deposited on a large rock in-stream. The spraint was composed of fish, likely to be mainly brown trout. Otter spraints (as found here) often occur in conspicuous places to indicate territories. Although this positive record confirms the species use of the corridor, it does not indicate frequency, nor does it indicate that the watercourse can support a breeding population. It is more likely that Sea Cut provides preferential riparian habitat for breeding with overhanging trees and buttresses that provide potential for natal holts.

Otters are likely to utilise the entire stretch of Burniston Beck as a part of an individuals territory, the home range being ultimately dependant on the carrying capacity of the water course (prey biomass and holt availability). The lower reaches of the beck (and especially the confluence with Sea Cut) are likely to provide most interest and are important due to the high proportion of cover, territorial importance and relatively little disturbance.

It should be noted that the spraint site was located upstream of Cow Wath bridge, this indicates that a) the bridge does not pose a substantial barrier to movement and b) that otter are also present in the upstream reaches.

Given that otter territories are large (extending up to 40km) and the variability of their home range, the precautionary approach should be taken with regard to flood alleviation in this area. Field evidence together with English Nature records indicate that otters may be active throughout the entire catchment, moving upstream from Sea Cut and using the local becks including Burniston, Cloughton, Quarry and Lindhead.

A thorough survey for otter should be undertaken on Burniston Beck. Works that are likely to affect the steep sided banks present from Cow Wath bridge to Sea Cut should be avoided.

Any work that affects riparian trees, areas of dense ruderal (tall herb e.g. nettle / willowherb) or scrub vegetation should be avoided. Should the scheme affect a feature that is used by otters, a licence will be required from English Nature in order for works to continue.

Kingfisher (*Alcedo athis)*

An assessment of the habitat on the lower reaches of Burniston Beck revealed that there is considerable potential to support kingfisher at this location due to the steep sided banks and good fisheries interest. A thorough survey for potential breeding sites should be undertaken on Burniston Beck and works that are likely to affect the steep sided banks present from Cow Wath bridge to Sea Cut should be avoided. The kingfisher is afforded protection under Schedule 1 of the Wildlife and Countryside Act 1981 (as amended) and Annex 1 of EC Directive 79/409./EEC.

Fisheries

Brown trout (Salmo trutta) were recorded along the course of Burniston Beck with numerous small and medium sized individuals evident on the stretch between Beaconsfield Farm and White Cabin. The presence of salmonids may indicate good water quality and high oxygen levels along Burniston Beck and the abundance of fish recorded indicates a high biomass. Local fisheries records should be sourced at the next stage in order to determine the requirement for further survey and predict the potential impact of scheme.

Invertebrates

Due to the clean waters indicated by the presence of brown trout, the beck may support some invertebrate interest, consultation with the local specialist recorder, the Environment Agency or the Biological Record Centre at the next stage of assessment may determine the necessity for further surveys.

Other species of nature conservation interest

The area, of which the beck corridor is part, provides potential to support species of conservation concern including Biodiversity Action Plan (BAP) and protected species. This includes bat species, brown hare (Lepus europea), barn owl (Tyto alba), skylark (Alauda arvensis), lapwing (Vanellus vanellus) grey partridge (Perdix perdix) and corn bunting (Emberiza clandra). The habitats associated with the corridor are capable of supporting a variety of small birds (for example large numbers of goldfinch (Cardeuilis carduelis) were recorded feeding on stands of thistle in the riparian corridor).

Although in-stream schemes may not directly affect such species, any works that isolate the beck corridor from the surrounding habitats or remove amounts of existing vegetation should be avoided. Such proposals may have cumulative or residual impacts like the loss of cover, breeding sites or a reduction in available prey/forage. Schemes should be designed sensitively, retaining areas of dense scrub and trees along the corridor, whilst aiming to enhance integration with the surrounding habitat mosaic.

All birds, their nests and eggs are legally protected by the Wildlife and Countryside Act 1981 (as amended). Therefore any vegetation clearance or the demolition or alteration of bridge structures in which birds are nesting should be undertaken outside the breeding season to avoid damage or destruction of nests. The bird breeding season is dependant on local variation but runs from approximately mid-February to mid-September.

4.11 Invasive Species

No invasive species were recorded during the survey.

4.12 Mitigation and/or Enhancements

Significant features, Constraints and Recommendations

The entire reach of Burniston Beck constitutes a significant feature of conservation interest and especially the downstream reaches. This watercourse is an important tributary to Sea Cut, as such any scheme that will affect the overall water quality or the natural profile of the channel in the downstream reaches will be unacceptable and likely to be heavily constrained. The scheme should avoid all impacts to the downstream reaches of Burniston Beck.

The use of a flood storage area would be ecologically preferred and should be designed to be in keeping with the surrounding habitats

The following mitigation should be considered:

- a flood storage area, designed to enhance the existing nature conservation interest and contribute towards local biodiversity targets.
- where applicable, the creation of wildlife ledges in culverts and under bridges (both new and existing structures) to allow the passage of riparian mammals and badgers.
- No scheme should be considered that affects the channel or bank profile along the length of Burniston Beck, especially the downstream reaches from the salvage station

The following constraints are likely given the information available at this stage:

- confirmed presence of a legally protected species: Any proposal on Burniston Beck should seek advice and agreement with English Nature in its design and location with regard to otters.
- vegetation along Burniston Beck from the salvage station (Target note 3/Map 3) to Sea Cut is likely to provide resting sites, holts or hovers for otter and should not be disturbed;
- If an otter holt or resting site is discovered and is likely to be affected English Nature must be consulted on how to proceed. It will not be acceptable to remove it without considering alternative options.
- It is likely that a licence will be required from English Nature as otters are confirmed to be resident and may be physically disturbed by any operation on the beck. A mitigation package will be required: This may involve artificial holt creation, habitat improvements/widening of the riparian corridor and/or provision of wildlife ledges.
- possible presence of legally protected and BAP species: bats badger, water vole and kingfisher. A licence will be required from Defra should badgers (and/or their setts) or bats (and/or their roosts) be affected by the proposals. As detailed for otters, this will require the consideration of alternative schemes working practices, and the design and implementation of a detailed mitigation package.
- potential to support important fisheries;
- the retention of the channels existing form: no piping should be undertaken;
- existing vegetation should be retained where possible;
- work should be undertaken outside the bird nesting season:

The following are recommendations for further consultation or survey:

- a bat survey should be undertaken should the scheme be anticipated to involve the removal of trees;
- detailed flora survey;
- further otter surveys and consultation with English Nature, the local otter recorder and Yorkshire Wildlife Trust;
- water vole surveys and consultation with the Yorkshire Wildlife Trust;
- consultation with the local badger group and badger surveys;
- survey and consultation regarding local fisheries;
- consultation with local recorders with regard to invertebrates;
- a detailed River Corridor Survey (RCS)
- close liaison with Yorkshire Wildlife Trust with regard to the design and implementation of flood storage measures, should these be proposed

5 Hydrological Modelling

5.1 Catchment Definition

Burniston Beck is a small watercourse flowing in a southerly direction and located to the north of Scarborough. The origin of the watercourse is the confluence of Cloughton Beck and Quarry Beck. The watercourse then runs down the east side of Burniston and into the Sea Cut east of Scalby (a village to the north west of Scarborough). The upper reaches of the watercourse are almost entirely rural. From a weir and lake upstream of Cloughton Bridge, the watercourse splits into two tributaries: West Beck and East Beck, both of which incorporate weir structures. These Becks converge in a Public Open Space behind the Village Hall running then as a single watercourse along the edge of Burniston and farmland.

Cloughton Beck is steep in its upper reaches (1:50 approximately), and the surrounding area is characterised by a mixture of farmland and woodland. Quarry Beck is a flatter gradient of approximately 1:220 and is largely characterised by farmland with some woodland in the upper reaches. Downstream of the confluence of Quarry and Cloughton Beck the gradient flattens (1:330) and the catchment is characterised by a mixture of residential area and fields.

Burniston Beck drains a total catchment area of 21.0km^2 and using the Flood Estimation Handbook (FEH) URBEXT parameter as a guide, is approximately 2% urbanised. The underlying geology of the catchment is Jurassic sandstone, limestone and shales overlain predominantly by a cover of boulder clay.

The Burniston Beck catchment is depicted in Appendix A.3 along with the sub-catchments of Cloughton Beck and the Quarry Beck. Table 5.1 summarises some of the hydrological and hydraulic characteristics of the Burniston Beck, Cloughton Beck and Quarry Beck catchments.

Table 5.1 - Catchment Characteristics

	Burniston Beck (whole catchment)	Cloughton Beck	Quarry Beck
Catchment Area (km^2)	21.02	2.89	13.48
Length of Watercourse (km)	5.0	3.7	5.1
URBEXT	0.004	0.017	0.012

5.2 FEH Methodology

The primary aim of the hydrological assessment is to derive design flows for input into the hydrodynamic model (ISIS) of the Burniston Beck open channel flow system. Design flow estimates have been derived for the, 5, 10, 25, 50, 75, 100 and 200 year return periods for the catchments of Cloughton Beck and Quarry Beck upstream of their confluence which is the start of Burniston Beck, and for the whole of the Burniston Beck catchment upstream of its confluence with the Sea Cut. Design inflow hydrographs have been generated for the Burniston Beck catchment in accordance with the FEH.

Burniston Beck is an ungauged catchment, and therefore FEH procedures for ungauged ('no-data') catchments have been used to model catchment hydrology. The key stages in the FEH analysis are as follows:

1. Use of FEH CD-ROM 1999 to determine catchment descriptors;

2. Application of WINFAP-FEH (FEH software package) to derive a pooling group of hydrologically similar catchments;

3. Estimate of Q_{MED} (the median annual flood) from catchment descriptors, and adjustment using analogue catchments;

4. Statistical estimation of peak flows for different return periods from the product of Q_{MED} and growth curves obtained from the pooling group;

5. Application of FEH rainfall-runoff method to derive hydrographs for the various return periods using synthetic unit hydrographs;

6. Reconciliation of the two methods for the purpose of design flows.

5.2.1 Statistical Analysis

The statistical derivation of flows for Burniston Beck catchment is summarised in Appendix C.1 (Section 4).

As the Burniston Beck catchment is ungauged, an estimate of the median annual flood (Q_{MED}) is derived initially from digital catchment descriptors. Estimating Q_{MED} for an ungauged catchment by catchment descriptors alone can be inaccurate. The FEH, therefore, recommends that, for an ungauged site, a method to improve Q_{MED} is to adjust the estimated Q_{MED} on the basis of data collated from a 'donor' or 'analogue' catchment, which has an extensive flow record. A donor catchment is a local catchment with gauged data particularly relevant to flood estimation at the subject site. The ideal donor catchment is one sited just upstream or downstream of the subject site. An analogue catchment is a more distant gauged catchment which is sufficiently hydrologically similar to the subject site to make the data relevant.

It was deemed that there is no appropriate donor gauge for Burniston Beck and therefore sites within the pooling group that are geographically close to the subject site (ie: within the North East) have been adopted as analogue catchments. The adjustment ratio using the analogue catchments varied, with the average value approximately equal to 1.2. The average ratio derived from the relevant analogue catchments was subsequently used to adjust the catchment descriptor estimates of Q_{MED} (refer Appendix C.1, Table 4.2).

It is noted that an alternative method of calculating Q_{MED} is deriving an approximation on the basis of a typical bankfull width for a natural watercourse (determined based upon cross sections throughout a reach). In this instance, Q_{MED} values derived on this basis are generally larger than those derived using the catchment descriptor method (refer Appendix C.1, Table 4.3). These values suggest, therefore, that the adjustment ratios derived from analogue catchments may give a more representative Q_{MED}.

The initial selection of a pooling group for an ungauged catchment is automated by WINFAP-FEH. The WINFAP database is queried to identify gauging records relating to catchments that may be considered 'hydrologically similar' to the subject site which are determined on the basis of catchment descriptors. Sufficient data is collated initially to provide '5T' station years of data, where 'T' is the target return period - in this case 100 years. These sites are subsequently reviewed and tested for discordance and heterogeneity, and the pooled data is then used to produce growth curve estimates that, in conjunction with Q_{MED}, determine the statistically derived peak design flow estimates for the catchment. The derivation and adoption of the Burniston Beck pooling group is summarised in Appendix C.1 (Table 4.7).

5.2.2 Rainfall-Runoff Method

The derivation of the rainfall-runoff model is summarised in Appendix C.1 (Section 5). The rainfall-runoff method predicts flows by relating rainfall and the hydrological response of a catchment to a storm event.

Three key parameters are used by the rainfall-runoff model to define the hydrological characteristics of a catchment, and since Burniston Beck is ungauged these have been determined from catchment descriptors (FEH CD-ROM). These parameters are:

(i) Catchment response to rainfall (time-to-peak, T_p);

(ii) Proportion of rainfall which directly contributes to river flow (percentage runoff, PR);

(iii) Quantity of flow in the river prior to the storm event (baseflow, BF).

Rainfall is defined in terms of duration, depth and distribution (over time), and may relate to either a probabilistic design event, eg: 1 in 100 year return period, or an observed storm event (for calibration purposes). Where a design event is to be analysed, the storm duration (D) is determined as a function of catchment response (time-to-peak, T_p) and Standard Annual Average Rainfall (SAAR). The derivation of rainfall depth is automated using the FEH Rainfall-Runoff module within ISIS for a particular return period of a given storm. An aerial reduction factor is subsequently applied, and the rainfall hyetograph (rainfall distribution over time) is defined using a standard profile. For the Burniston Beck catchment the FEH 75% winter profile was used together with a catchment wide storm.

5.3 Rational Method

The Rational Method provides an alternative means of estimating peak flows for all of the Burniston Beck sub-catchments.

The Rational Method uses runoff coefficients and rainfall intensity to calculate peak flows for a given catchment area. The runoff coefficients are dependent on land use, rainfall intensity and return period, and for a 100 year event, the coefficients range from 0.34 to 0.41 for the sub-catchments. Lower return period events have slightly lower runoff coefficients.

Further details of the Rational Method, the runoff coefficients used and the results can be found in the calculation record in Appendix C.1.

5.4 Design Flows - Discussion

Peak flows have been calculated for the hydrological assessment locations using statistical pooling analysis, rainfall-runoff and the Rational Method. These flow estimates for various return period events are presented graphically in Appendix C.11 to C.12 and in Table 5.2.

Table 5.2 - Peak Flow Estimates (m^3/s)

Return Period (years)	Cloughton Beck			Quarry Beck			Entire Burniston Beck		
	Statistical	Rainfall-Runoff	Rational	Statistical	Rainfall-Runoff	Rational	Statistical	Rainfall-Runoff	Rational
Q_{MED}	0.96	0.93		5.00	4.93		7.71	5.98	
5	1.50	1.29	1.50	7.47	6.88	5.00	10.86	8.27	6.69
10	1.91	1.66	1.93	9.28	8.70	6.40	12.91	10.48	8.50
25	2.55	2.18	2.57	11.93	11.35	8.47	15.58	13.64	11.16
50	3.12	2.64	3.32	14.26	13.65	10.90	17.68	16.39	14.29
75	3.50	2.90	3.67	15.72	14.92	12.04	18.96	17.91	15.74
100	3.80	3.11	3.98	16.86	15.97	13.03	19.88	19.16	17.01
200	4.61	3.68	4.78	19.89	18.80	15.62	22.22	22.54	20.29

The rainfall runoff flow estimates are lower than the statistical flow estimates for all the points where flows have been estimated. There is a good comparison between the flow estimates using the Rational Method and the Statistical Method for Cloughton Beck. However, for Quarry Beck and Burniston Beck flow estimates derived using the Rational Method are much lower than either the Statistical or Rainfall Runoff Method. The validity of the FEH statistically derived flow regime is heavily dependent upon how suitably the adopted pooling group represents the catchment of interest. The catchments within the pooling group appear to compare well with the Cloughton, Quarry and Burniston Beck catchments and the Statistical Method is considered to be the preferred method. The Statistical Method provides only peak flow for a particular return period but a full hydrograph is required for an unsteady hydrodynamic model. Therefore, the rainfall runoff method with a catchment wide storm will be used to derive inflows into the hydraulic model and will be scaled to the statistical method peaks.

6 Hydraulic Modelling

6.1 General

The primary aim of the hydraulic modelling is to predict peak design water levels throughout the watercourses system to derive flood depths for input into the Cost Benefit Analysis. The model also serves to assess flood alleviation options.

The hydraulic analyses of Cloughton, Burniston and Quarry Becks have been undertaken using ISIS (Version 2.0), a one-dimensional hydrodynamic model. The hydrodynamic facility is particularly prevalent in the context of this river system due to the tributaries. As it is fundamental to the hydraulic modelling to get the timing of the peak flows on the tributaries correct to accurately assess flood storage effects along the watercourses. This can simply not be achieved within the confines of a simple steady-state (peak flow) regime.

Peak design water levels have been assessed for the 5, 10, 25, 50, 75, 100 and 200 year return periods. As an ungauged catchment with limited rainfall and no recorded water levels, a definitive calibration of the ISIS model has not been possible but verification of the model for the recent flooding in October/November 2000 has been undertaken.

The Cross section locations and the adopted ISIS representation of the Cloughton, Burniston and Quarry Becks system are presented in Appendix A.4 and Appendix A.5 respectively.

6.2 Flooding Flow Routes

The majority of the flood waters escaping from the watercourses will flow along the side of the watercourse with minimal pooling. The only area where some pooling of floodwater has been observed is West Lane in Cloughton. These flow routes were assigned in MapInfo by analysing data from the following sources:

- topographic survey, including spot levels on roads and threshold levels of properties;
- historical records of flooding within Cloughton and Burniston (see Table 2.1); and,
- an assessment of potential flow routes during site visits.

Appendix A.6 shows the flood flow routes that have been determined and incorporated into the hydraulic model.

6.3 Schematisation of the River System

6.3.1 River Channel

The schematisation of the Cloughton, Quarry and Burniston Becks system was undertaken on the basis of the topographic survey (refer Section 3.1) and collated in order to describe the physical properties of the channel. (This is presented in Appendix A.5)

Typically cross sections are spaced at intervals of approximately 200 metres along the length of the channel, positioned on the basis of their surveyed chainage and forming the basis of the computational model. To model the roughness of the channel, Manning's 'n' values have been adopted on the basis of survey photography (refer Appendix B) and site reconnaissance visits, defined in accordance with appropriate values as depicted in 'Open Channel Hydraulics' (Chow, 1959). The design roughness regime for the Cloughton, Quarry and Burniston Becks system has been adopted as 0.060 and 0.080 for the channel and overbank areas respectively. This relates to the channel being relatively overgrown.

6.3.2 Hydraulic Structures

A total of fourteen (14) bridges and culverts were identified along the Cloughton, Burniston and Quarry Becks model reaches, in addition to one (1) weir structure and eight (8) natural weirs. Each structure was assessed individually and modelled appropriately (see Table 6.1).

Table 6.1 – Hydraulic Structures (refer to Appendix A.4)

Model Chainage	Name of Structure	ISIS Unit
CLO01_01134	West Lane Culvert	Twin Orifice with overtopping Spill
CLO01_00383	Field Access Track Bridge	Orifice with overtopping Spill
BUR01_04527	Weir Structure at channel split	Spill
BUR01_04445	Cloughton Bridge	Orifice with overtopping Spill
BUR01_04050	Natural Weir	Spill
BUR01_03698	Natural Weir	Spill
BUR01_03027	Rocks Lane Bridge	Twin Orifice with overtopping Spill
BUR01_03017	Natural Weir	Spill
BUR01_02792	Bridge Close Bridge	Orifice with overtopping Spill
BUR01_02700	Willymath Bridge	Orifice with overtopping Spill
BUR01_02698	Natural Weir	Spill
BUR01_02188	Natural Weir	Spill
BUR01_02014	Stone Arched Access Track Bridge	Orifice with overtopping Spill
BUR01_01905	Access Track Bridge u/s of caravan park	Orifice with overtopping Spill
BUR01_01597	Bridge to Salvage Station	Orifice with overtopping Spill
BUR01_01595	Natural Weir	Spill
BUR01_00563	Natural Weir	Spill
BUR01_00556	Cow Wath Bridge	Orifice with overtopping Spill
BUR01_00288	Natural Weir	Spill
BUR02_04397	Cloughton Bridge (secondary channel)	Orifice with overtopping Spill
BUR02_04368	Driveway Bridge	Orifice with overtopping Spill
BUR02_04220	Footbridge	Orifice
BUR02_04155	Footbridge	Orifice

6.3.3 Floodplain Areas

Where initial model results suggested that the predicted peak water levels exceeded the extent of the cross sections surveyed, floodplain areas were delineated using additional topographic survey and site observations, and then incorporated into the ISIS model at appropriate locations.

6.3.4 West Lane & Little Moor Close Area

The culvert under West Lane is undersized. This causes floodwater to spill onto West Lane and flood properties in the West Lane and Little Moor Close area. The floodwater does pond here before reaching a level to return into Cloughton Beck downstream of the West Lane culvert. To represent this occurrence in the hydraulic model a spill has set at the road level above the culvert, this spills into a reservoir area and a spill unit has been set to the level when flow would return into Cloughton Beck. This arrangement allows depths of flooding to be calculated to the surrounding properties.

6.4 Boundary Conditions

6.4.1 Catchment Hydrology

Design flow hydrographs have been derived for inflows at the upstream limits of Quarry and Cloughton Becks and two lateral inflows for Cloughton Beck (downstream of West Lane culvert) and Burniston Beck (at BUR01_002865) for the 10, 25, 50, 75, 100 and 200 year return periods respectively in accordance with procedures outlined in the Flood Estimation Handbook (FEH). Adopted peak design inflows for the hydraulic model are summarised in Table 6.2 below, however the hydrological analyses undertaken as part of this investigation are summarised in detail in Section 5 of this report.

Table 6.2 - Adopted Peak Design Inflows (m^3/s)

Return Period (years)	Quarry Beck Peak Flow (m^3/s)	Cloughton Beck Peak Flow (m^3/s)	Cloughton Beck Lateral Peak Flow (m^3/s)	Burniston Beck Lateral Peak Flow (m^3/s)
10	8.2	1.3	0.39	2.6
25	11	1.8	0.53	3.4
50	13.4	2.3	0.65	4.2
75	14.7	2.65	0.72	4.6
100	15.8	2.9	0.77	4.9
200	18.8	3.6	0.92	5.8

The peak design inflow represents the sub catchment areas.

6.4.2 Downstream Conditions

The downstream limit of the hydraulic model is the confluence with Sea Cut. The governing downstream boundary adopted for design purposes has been defined as a Discharge-Height (Q-H) relationship, determined on the basis of normal flow depth conditions. A sensitivity analysis has subsequently been undertaken to ascertain the impact upon upstream water levels Burniston Beck associated with high water levels in Sea Cut. The result of this sensitivity analysis shows that due to the steepest of Burniston Beck there was a minimal affect on river levels.

6.5 Model Verification

No calibration data is available for Cloughton, Quarry and Burniston Becks so the model has only been verified and not calibrated. Verification of the hydraulic model involves the input of a recorded rainfall event and comparing the resulting stage with those levels recorded by residents through questionnaires and photographs. Calibration involves checking the predicted water levels from the model to actual levels recorded in the field.

The events selected for verification were the June 2000 and October/November 2000 events for which rainfall data was obtained from the Environment Agency. There is only one tipping bucket rain-gauge within the vicinity of the catchment, which is at Keld Head. The Percentage Runoff and the Catchment Wetness Index were adjusted for the event based on the previous 5 days of rainfall. The June 2000 event (estimated return period 5 years) was a shorter duration event than the October 2000 event (estimated return period 15-25 years) and it resulted in lower levels. From the collected residents' questionnaires and photographs the level of flooding appears to compare well with that predicted by the model.

6.6 Sensitivity Analysis

A sensitivity analysis has been undertaken to ascertain the impact upon peak design flood levels of variations in critical design parameters, which is particularly useful for an uncalibrated model. The following sensitivity analyses have been undertaken based upon 1 in 100 year design event flow estimates.

6.6.1 Roughness Regime

Manning's 'n' included in the model is based solely upon visual inspection. On this basis, an assessment of the sensitivity of predicted peak water levels to variations in channel and over-bank roughness is imperative. The impact upon peak design flood levels resulting from a variation in Manning's 'n' of +20% (ie: $n_{channel}$ 0.060 (design) to 0.072; $n_{overbank}$ 0.08 (design) to 0.096 has been considered. This resulted in minimal changes in water level along the modelled river system. The design Manning's 'n' value was determined using information collected during site visits, photographs and engineering knowledge. The effects of reducing the Manning's 'n' by 20% resulted in a maximum change of ±100mm in water level. However, the average change along the watercourses was ±50mm. These changes are considered relatively small.

6.6.2 Climate Change

It is recommended that climate change be considered via a 20% increase in design flow over the next 50 years. To this end, a sensitivity assessment has been undertaken to provide some indication of the potential impacts that climate change (assuming a 20% increase in the 100 year design flow) may have upon flood levels throughout the catchment. The result is a 360mm (maximum) increase in peak water level upstream of the Willymath Bridge and only an average of 100mm throughout the rest of the watercourse. The large increase observed at Willymath Bridge is due to the backing up of flow.

6.6.3 Structure Blockage

During site visits it was noted that debris had collected around the structure inlets. This was confirmed by responses to the questionnaires distributed to the local residents during the critical watercourse study. There were many reports of debris blocking the culvert inlets.

Potential blockages of five key structures were analysed by reducing the bore area of the structures by 50 & 75% to determine the affects on the water levels. The table below shows the increase in water level directly upstream of the culvert.

Table 6.3 – Affects of Structure blockage (at upstream face)

Structure	Water Level increase for 50% blockage	Water Level increase for 75% blockage
West Lane Culvert (CLO01_01134)	36mm*	45mm*
Cloughton Bridge (BUR01_04445)	352mm	518mm
Rocks Lane Bridge (BUR01_03027)	138mm	230mm
Bridge Close Bridge (BUR01_02792)	111mm	181mm
Willymath Bridge (BUR01_02700)	530mm	730mm

* = increase in flood depth of storage area

From the analysis it can be seen that West Lane culvert is undersized to start with and therefore any further blockage has only a limited affect. The increase in water level upstream of Cloughton Bridge is limited to 70m reach due to the weir upstream. The blockages at Cloughton Bridge will cause the A171 to be flooded. The blockage at Rocks Lane has an influence on water levels up to 200m upstream. The blockage for the Bridge Close Bridge affects water levels up to Rocks Lane Bridge. At Willymath Bridge the affects of blockage cause the water level to rise significantly. Therefore, it is essential to keep the culverts free from blockage.

6.7 Flood Extents

The hydraulic model was run for the existing situation for the 10, 25, 50, 75, 100 and 200 year design flows. It was found that in a 10 year event there was some out of bank flow in the West Lane area. Flooding is predicted to occur in this area due to the incapacity of the culvert and its inability to convey the flow.

Flooding in the Becks Lane area is caused by channel incapacity, flooding is predicted to occur at a return period of 50 years and above.

In the Bridge Close area flooding is caused by a combination of channel incapacity and the constriction of the Bridge Close Bridge. Flooding occurs for event with a return period of 25 years and above.

In the Rocks Lane Bridge area flooding occurs downstream of the bridge for return periods of 50 years and above. However, upstream of the bridge flooding occurs but does not affect properties until a 100 year return period event.

Flooding of the caravan park starts at a return period of 25 years.

The flooding extents for various return periods are outlined in Appendix A.7.

7 Discussion of Measures to Mitigate Flooding

In this section, various flood defence measures are discussed to address specific flooding problems around the catchment. Some of these measures are then combined to form a set of solutions.

7.1 Measure 1 – Flood Flow Retention Storage

It is always necessary to consider options from a strategic point of view to ensure that the catchment is assessed holistically. Upstream flood storage is becoming increasingly important and is already utilised on both large and small catchments. The limitations of this method should also be noted, namely the large area of suitable land that is required and the inherent susceptibility to sustained and frequent events.

The main area of flooding along Cloughton Beck is at the upstream limit of the model (Little Moor Drive and West Lane). Due the catchment being extremely steep there are no sites/areas of required size to provide the necessary storage for the flow. Any storage here will only reduce flooding for Cloughton Beck as Quarry Beck peak flow is over 5 times that of Cloughton Beck.

Most of the fields along the banks of Burniston Beck act as floodplains during extreme events, therefore it is important to retain these areas. There is one possible location for storage within the catchment. The area at the confluence of Quarry and Cloughton Becks with Burniston Beck has the potential to store water from both tributaries which can be used to reduce flows through Burniston.

For a 1 in 100 year return period event (Q100) the offline storage at the confluence and surrounding area has been assessed. In order to model the option of offline storage, the peak flow for Burniston Beck downstream of Cloughton Bridge would have to be reduced from 18.8m^3/s to 9.5m^3/s (for Q100 event). The reduction in peak flow represents the maximum flow capacity of the channel. The minimum volume of offline storage required for the design Q100 flood event is 170,000m^3 (In reality, due to the natural inefficiencies of a flood storage solution, this volume could easily be 2-5 times the minimum required). The result in limiting the maximum flow in the channel to 9.5m^3/s this would eliminate the flooding of properties downstream of Cloughton Bridge, however, there would be surface water flooding of the caravan park.

It is concluded that to provide this volume of storage would require up to four metre high embankments, substantial earthworks and complex flood flow diversion channels/structures. It is estimated that these works will cost approximately £3 million. Therefore it was decided not to progress this option any further.

7.2 Measure 2 - Localised Defences

In this option the following defences are considered:

(i) Constraining Cloughton Beck channels with embankments/floodwalls on the left bank including a speed hump structure across Beck Lane (looking downstream).

(ii) Flood bunds on the left hand bank upstream and both banks downstream of Rocks Lane Bridge.

(iii) Floodwall on the right bank both upstream and downstream of Bridge Close Bridge.

(iv) Flood bund along the left bank of Burniston Beck adjacent to the caravan and camp sites.

No channel widening work is assumed and no changes to structures allowed for.

The water levels from the hydrodynamic model were compared with the bank levels, and channel bank levels were altered within the model such that water was contained within the channel. A 300mm freeboard level (considered low) was also added onto the required bank levels to take into account, for example, climate change, modelling uncertainty and construction errors. For each of the nodes in the model the height of embankment required is tabulated in Table 7.1. The locations of these nodes and the length of the embanking are shown in Appendix A.8.

Table 7.1 - Height of Embanking required at selected nodes in the model (including 300mm freeboard) for Q100 (see Appendix A.4 for model node location)

Model Chainage	Description	Required Length of Embankment (m)	Required Height of Embanking	
			Left Bank (mm)	Right Bank (mm)
CLO01_00643	Becks Lane	250	600	-
BUR01_03027	U/S Rocks Lane Bridge	30	400	-
BUR01_03017	D/S Rocks Lane Bridge	75	500	-
BUR01_03017	D/S Rocks Lane Bridge	150	-	500
BUR01_02792	U/S Bridge Close Bridge	60	-	1000
BUR01_02705	D/S Bridge Close Bridge	70	-	600
BUR01_01905	U/S limit of Caravan Park	450		1200
BUR01_01767	Caravan Park			1000
BUR01_01600	D/S limit of Caravan Park			850

Table 7.1 shows the lengths of embanking required along Cloughton and Burniston Becks. The embankment would have to be completed in such a way that it does not obstruct any of the public footpath which run along the side of the watercourse here. Constructing the flood bund along the riverbanks would lead to a small increase in the water level in the channel and the opposite bank floodplain. This has been assessed when calculating the level of embankment/floodwall required. The measure of flood embanking/floodwalls can not be used to address the flooding issues at West Lane. This is due to the topography of the area. The construction of flood bunds and walls cannot be used to resolve all the flooding issues within the catchment.

7.3 Measure 3 - Improvements to Structures

There are several structures which are overtopped during extreme events along Cloughton and Burniston Becks. The majority of these structures are field access track bridges, which are not believed to have a significant affect on the flooding outline. However, there are three structures which are bypassed or overtopped that cause flooding to surrounding properties.

- West Lane Culvert
- Rocks Lane Bridge
- Bridge Close Bridge

West Lane culvert is severely undersized and causes flooding at a 1 in 10 year return period. To resolve this, the current twin pipe culvert would need to be replaced with a 1.5m by 1.2m box culvert. This size culvert would provide the necessary capacity to convey a 1 in 100 year without surcharging. To enlarge the culvert size the channel downstream would need widening, see section 7.4 for the requirements.

Rocks Lane Bridge is a historic twin arched stone bridge. The structure is overtopped during extreme events. It is not believed that any structural alterations could be made to the bridge due to its age and historical importance. Therefore, the only option would be a bypass channel and culvert under the road. However, this is not recommended as Bridge Close Bridge is only 230 metres downstream of Rocks Lane Bridge. This area is affected by flooding already and by providing a bypass route for the flow around Rocks Lane Bridge would increase the flow causing additional flooding. It is anticipated that the cost of a bypass channel and culvert would cost approximately £4-500,000. Therefore this option has been dismissed.

It has been reported by local residents that the soffit level of Bridge Close Bridge is too low and this is contributing to the flooding problem in the area. From a review of the topographical survey it shows that the soffit level of the bridge is 400mm lower that the right bank level. Therefore, to increase the capacity of the bridge the only option is to change the bridge from an arch to a flat deck bridge. This change has been modelled using ISIS and only reduced the water level by 50mm for a 1 in 100 year event. It was decided that any changes to the bridge would not reduce the water significantly to reduce flood risk and therefore, this option was dismissed.

The locations of the structures and the works proposed for West Lane are illustrated in Appendix A.9.

7.4 Measure 4 – Channel Widening

The channel downstream of West Lane culvert is extremely narrow. The top width of the channel is less than 2m. To enable the new culvert to operate to its full potential the channel downstream of the existing culvert requires widening.

The proposed works are a widening of the channel for approximately 120 m from the downstream face of West Lane culvert such that the flow is maintained within the banks for higher return periods. The depth of the channel along this reach will remain the same. The banks of the widened channel will be gentle slopes reducing the risk of bank instability and the height of banks will be designed including 300mm freeboard. The location of the channel widening is illustrated in Appendix A.10.

7.5 Measure 5 – Temporary Defences

This looked at the possibly of using stop-log and pallet barriers that could be stored locally and erected before a flood event was expected. This idea has been used successful on a number of rivers through the UK. However, for Burniston and Cloughton Beck this is not feasible, the watercourses are at risk from flashy flood events and there are numerous sites to protect. Therefore, this does not provide the required lead in time to issue a flood warning and mobilise personnel to deliver the temporary defence to site and erect the structures.

8 Description of Flood Mitigation Options

The following options have been considered to alleviate flooding from Cloughton and Burniston Becks. These options have been taken forward for detailed cost benefit analysis.

8.1 Option 1 - Do Nothing

Under the 'Do Nothing' option, the present maintenance scheme would cease and no additional or maintenance works would be undertaken. Flooding would occur on a regular basis due to blockage of and silting of the culverts and parts of the channel, resulting in regular flooding and damage to a large number of residential properties.

It should be noted that the 'Do Nothing' case is the baseline against which all other schemes are measured and would require SBC to effectively 'walk away' from the problem. A portion of the damages associated with this case then become the benefits of providing a scheme as some of these damages are avoided.

8.2 Option 2 - Do Minimum

A 'do minimum' option is considered to be the minimum required to maintain the status quo or to undertake cost-effective measures that may increase the standard of protection sensibly. These measures are not emergency works, but could be a combination of maintenance and enhancement and are not intended to involve significant capital works.

In this case, the 'do minimum' option would be to ensure that the potential capacity of the watercourse is not reduced through silting and weed growth or through blockages at structures. No additional engineering work would take place, but the present maintenance regime would be continued and enhanced. This would be combined with emergency response measures, with the provision of sand bags and flood warning systems. It should be noted that the latter measures will be limited in their effects due to the flashy nature of the flooding in this area.

This option (and others) could be combined with the introduction of flow and rainfall gauges, whereby future assessments could be undertaken to deal with the current uncertainty relating flow predictions and observed historical flooding data. In this scenario further assessments would be carried out after a reasonable length of data has been collected, after at least 5 years. However, it should be noted though that the quality and length of data required before reliable conclusions could be made is uncertain.

Under this option, flooding would still occur as no capital work is proposed for the existing culvert which is considered under-capacity.

8.3 Option 3 – Localised Defences, Improvements to Structures and Channel Widening

The measures discussed in Section 7 provide solutions to localised flooding within the areas of the catchment. To develop a solution a combination of measures is the preferred solution to preventing flooding in for the whole area. This combined option will incorporate the improvements to the West Lane culvert (Measure 3), flood embankments/floodwalls (Measure 2) and channel widening (Measure 4). Works to the culverts will solve the issues surrounding the potential for flooding by increasing the capacity of the culvert. The level of the flood bund/walls is the same as for Measure 2. The level of embanking/walls for various return periods is summarised in Table 8.1 and the location of the works for Q100 standard of protection are illustrated in Appendix A.11.

Table 8.1 - Height of flood embankments and flood bund for various return periods

Location of Embanking	Return Period (years)			
	25	50	100	200
Height of Flood Embankment at Becks Lane (CLO01_00643) with 300mm freeboard	400mm	500mm	600mm	750mm
Height of Flood Embankment U/S Rocks Lane Bridge left bank (BUR01_03027) with 300mm freeboard	-	-	400mm	500mm
Height of Flood Embankment D/S Rocks Lane Bridge left bank (BUR01_03017) with 300mm freeboard	-	400mm	500mm	650mm
Height of Flood Embankment D/S Rocks Lane Bridge right bank (BUR01_03017) with 300mm freeboard	-	400mm	500mm	650mm
Height of Floodwall U/S of Bridge Close Bridge right bank (BUR01_02705) with 300mm freeboard	600mm	850mm	1000mm	1200mm
Height of Floodwall D/S of Bridge Close Bridge right bank (BUR01_02705) with 300mm freeboard	-	-	600mm	1000mm
Average Height of Flood Embankment at caravan park (BUR01_01767) with 300mm freeboard	500mm	750mm	1000mm	1500mm

8.4 Option 4 – Localised Defences, Improvements to Structures, Channel Widening and Raising Caravan Floor Levels

This option is essentially Option 3 with the proposed caravan park bund replaced with a proposal to raise the caravans above the 100 year flood level.

The measures discussed in Section 7 provide solutions to localised flooding within the areas of the catchment. To develop a solution a combination of measures is the preferred solution to preventing flooding in for the whole area. This combined option will incorporate the improvements to the West Lane culvert (Measure 3), flood embankments/floodwalls (Measure 2) and channel widening (Measure 4). However, instead of providing an embankment for the caravan park it is proposed to raise the floor levels of the caravans and therefore reduce the internal damages. The levels of the flood bund/walls will remain the same as for Option 3 everywhere else. The location of the works for Q100 standard of protection are illustrated in Appendix A.11

9 Economic Appraisal Methodology

9.1 Objectives

The economic appraisal of various options presented in Section 8 was conducted in accordance with the PAG3, (Defra 2003). The purpose of conducting this appraisal was to test the economic feasibility of the proposed schemes to alleviate flooding from the Cloughton and Burniston watercourses.

9.2 Estimation of Flooding Depths

Flooding depths have been estimated from the water levels calculated by the ISIS model and the threshold levels of properties within the flood risk area. Appendix D summarises the depths of flooding for each property for various return periods. These depths of flooding have been utilised in the economic appraisal.

9.3 Depth Damage Data

There are no commercial properties, only residential properties at risk of flooding within Burniston and Cloughton catchments. Costs were attributed to each property based on the depth of internal flooding (see Section 9.2). Damage costs were estimated using the Flood Hazard Research Centre's "The Benefits of Flood and Coastal Defence: Techniques and Data for 2003" (also known as the Multi-coloured Manual or MCM) and figures were updated for inflation using RPI Index. The Type and Age and Social Class classifications were used to determine the appropriate table to be used for each residential property type. Two property types were assumed to be at risk from flooding; 1975-1985 detached houses, and 1975-1985 detached bungalows. The damages associated with flooding in each property type are summarised in Section 10.1 and detailed fully in Appendix E, including extracts from the MCM.

The properties affected are likely to experience flooding durations of less than 12 hours, due to the catchment characteristics. Thus, the scenario of 'less than 12 hours flood duration' were analysed to determine the associated damages to properties.

The flood depth for each property, or group of similar properties, was used to determine the correct column to be used in the tables of Chapter 4, annexe 4.1 from the MCM. From the tables only the row providing Total Damage was used to calculate residential losses (See Appendix E).

Residential losses for each residential property or group of similar properties, for each return period flood event were entered into FCDPAG3 spreadsheet in the Asset AAD tab and from this the Present Value of losses was estimated for each property.

9.4 Write-off Values

FCDPAG3 states 'Care should be exercised where the total present value of losses exceeds the current write-off value of the asset. In the case of domestic or commercial property it will usually be prudent to assume that the long-term economic loss cannot exceed the current capital value of the property'. Property write-off values have been estimated using a number of sources. The write-off value for the residential properties was determined from the HM Land Registry – Residential Property Report found on the internet for July-September 2003. Table 9.1 shows the write off values that have been adopted for the various property types at risk, although these are considered to be conservative.

Table 9.1 – Property write-off values

Property Type	Unit write-off (£k)	No. of units	Total (£k)
1965-1974 Detached House	200	3	600
1965-1974 Bungalow	100	40	4,000
1965-1974 Semi-detached House	140	10	1,400
1919-1944 Terrace House	120	7	840
Post – 1985 Detached House	250	7	1,750
1919-1944 Detached House	220	2	440
		Total	**9,030**

9.5 Options Analysed

The Options which were analysed as part of the economic appraisal are as follows:

1) Do Nothing
2) Do Minimum
3) Combined Option A
4) Combined Option B

For each of these options the benefits were estimated from the damages, along with the costs of implementing the scheme.

10 Assessment of Benefits

10.1 'Do Nothing' Damages

The 'Do Nothing' damages are used to provide a cost baseline for the economic appraisal of the various options. They are calculated assuming no maintenance, repairs or improvements are made to the existing channel and structures and that the Council effectively 'walks away' from the problem. The structures may become blocked and eventually collapse, damaging the property and roads above them and resulting in frequent flooding and the eventual loss of parts of the town.

10.1.1 Identification of Properties at Flood Risk

Flood outlines (see Appendix A.7) and flood depths for each event return period were determined by hydraulic modelling. Table 10.1 summarises the number of properties of each type that are at risk of flooding for the various return periods.

Table 10.1 - Number of properties at risk for various return periods

Return period (years)	No. of properties affected	Properties (numbers in brackets)
5	0	
10	8	West Lane
25	14	West Lane (8), Little Moor Drive (3), Bridge Close (3)
50	63	West Lane (8), Little Moor Drive (19), Church Beck Cottages (12), Beck Lane (7), Rocks Lane (10), Bridge Close (7)
75	67	West Lane (8), Little Moor Drive (19), Church Beck Cottages (12), Beck Lane (7) Rocks Lane (10), Heare Mal, Burnside, Bridge Close (7), Coastal Road (2)
100	69	West Lane (8), Little Moor Drive (19), Church Beck Cottages (12), Beck Lane (7) Rocks Lane (10), Heare Mal, Burnside, Bridge Close (7), Coastal Road (2), Beck Farm Cottages (2)
200	69	West Lane (8), Little Moor Drive (19), Church Beck Cottages (12), Beck Lane (7) Rocks Lane (10), Heare Mal, Burnside, Bridge Close (7), Coastal Road (2), Beck Farm Cottages (2)

The caravan park is affected by flooding for return periods of 1 in 25 years and above.

10.1.2 Residential Property Losses

Table 10.2 summarises the average damage detached bungalow property type, assuming internal flood (various depths) for less than 12 hours duration. The damage associated with each individual property for the various return periods are summarised in Appendix E.

Table 10.2 – Damages Assigned to Various Property Types

Property Type	Damages
1965-1974 Detached House	£41.13k average per property
1965-1974 Bungalow	£55.60k average per property
1965-1974 Semi-detached House	£36.33k average per property
1919-1944 Terrace House	£41.40k average per property
Post – 1985 Detached House	£42.84k average per property
1919-1944 Detached House	£30.27k average per property
Total for 69 properties	£3,360.755k

10.1.3 Adopted losses

The Present Value (PV) loss calculated in the FCDPAG3 spreadsheet for each property, or group of similar properties, was compared with the write-off value for the property and they are summarised in Table 10.3. The number of properties used in the write-off calculation was based on the number of properties at risk for the 1 in 100 year return period event. The combined write off values are greater than the combined PV damages for each property type for both the upper and the lower limits that have been estimated. Therefore, the PV damages have been used to estimate the losses without a flood defence scheme.

Table 10.3 – Adopted Loss Values

Property Type	PV damages (£k)	Write-off value (£k)	Adopted Loss (£k)
1965-1974 Detached House	123.39	600	123.39
1965-1974 Bungalow	2,223.85	4,000	2,223.85
1965-1974 Semi-detached House	363.28	1,400	363.28
1919-1944 Terrace House	289.77	840	289.77
Post – 1985 Detached House	299.93	1,750	299.93
1919-1944 Detached House	60.54	440	60.54
Total	**3,360.755**	**9,030**	**3,360.755**

10.2 'Do Minimum' Damages

The 'Do Minimum' option seeks to maintain the status quo with the structures and channel by implementing a regime of urgent repairs, regular maintenance and emergency measures. The modelled culvert and structure capacities have been calculated assuming they are free from silt and blockage. The channel has been modelled assuming that they are no constrictions. Annual Average Damage (AAD) has been calculated using these assumptions.

It is, therefore, reasonable to assume that the damages that will occur for the 'Do Minimum' option are equal to the AAD calculated for the 'Do Nothing' option, and will occur evenly over the economic design life. Emergency measures will have limited impact due to the flashy catchment regime.

10.3 Assessment of Option 3

10.3.1 Q25 Standard of Protection Damages

The results of the hydraulic modelling reveal that improving the existing twin pipe culvert under West Lane with a 1metre by 0.9metre box culvert will be sufficient to provide protection to all properties in the West Lane and Little Moor Drive area from the 1 in 25 year flood event. For the Beck Lane area construction of a flood embankment/floodwall for approximately 250m at an average height of 400mm is sufficient to protect all properties in this area from the 1 in 25 year flood event.

In the Bridge Close area a floodwall would need to be constructed upstream of the bridge for approximately 60m and an average height of 400mm to provide this level of protection. At the caravan park an embankment would be required for approximately 450m at an average height of 500mm. For events greater than the 1 in 25, floodwaters will overtop the flood defences causing damage to properties. Table 10.4 summarises the number of properties that are at risk of flooding for events greater than the Q25 return period. The damage associated with each individual property for the various return periods are summarised in Appendix E.

Table 10.4 - Properties at Risk

Return period (year)	No. of properties affected	Properties
5	0	-
10	0	-
25	0	-
50	63	West Lane (8), Little Moor Drive (19), Church Beck Cottages (12), Beck Lane (7), Rocks Lane (10), Bridge Close (7)
75	67	West Lane (8), Little Moor Drive (19), Church Beck Cottages (12), Beck Lane (7) Rocks Lane (10), Heare Mal, Burnside, Bridge Close (7), Coastal Road (2)
100	69	West Lane (8), Little Moor Drive (19), Church Beck Cottages (12), Beck Lane (7) Rocks Lane (10), Heare Mal, Burnside, Bridge Close (7), Coastal Road (2), Beck Farm Cottages (2)
200	69	West Lane (8), Little Moor Drive (19), Church Beck Cottages (12), Beck Lane (7) Rocks Lane (10), Heare Mal, Burnside, Bridge Close (7), Coastal Road (2), Beck Farm Cottages (2)

For each of the properties at risk, the adopted loss is determined by comparing the write off value with the present value damages. The number of properties used in the write-off calculation was based on the number of properties at risk for the 1 in 200 year return period event. Table 10.5 summarises the combined adopted losses for the properties at risk.

10.3.2 Q50 Standard of Protection Damages

The scheme that offers at least a Q50 standard of protection to all properties is everything included within the Q25 scheme. However, the following additions are proposed:

- Increase size of West Lane culvert, box culvert to 1.2m x 1m,
- Raise the Beck Lane area embankment by an average additional height of 500mm,
- Raise the floodwall at Bridge Close by 850mm,
- Raise the caravan park embankment by 750mm.

In addition to these works, flood embankments are required downstream of Rocks Lane Bridge on both banks to an average height of 400mm. The left bank (looking downstream) will extend for approximately 75m and the right bank for approximately 150m.

For events greater than the 1 in 50 year, flood waters will overtop the flood defences causing damage to properties. The number of properties that are at risk of flooding for events greater than the Q50 return period are the same as in Table 10.4. The number of properties used in the write-off calculation was based on the number of properties at risk for the 1 in 200 year return period event. The combined adopted losses for the properties for the Q50 scheme are summarised in Table 10.5.

10.3.3 Q100 Standard of Protection Damages

The scheme that offers at least a Q100 standard of protection to all properties is everything included within the Q50 scheme. However, the following additions are required:

- Increase West Lane culvert, box culvert to 1.4m x 1.2m,
- Raise the Beck Lane area embankment by an average height of 600mm,
- Raise the Rocks Lane Bridge embankment downstream average height to 500mm
- Raise the floodwall at Bridge Close by 1000mm,
- Raise the caravan park embankment by an average height of 1000mm.

In addition to these works, the channel downstream of West Lane culvert needs widening by 1m for approximately 120m, a flood embankment is required upstream of Rocks Lane Bridge on the left bank (looking downstream) to an average height of 500mm and a floodwall is required downstream of Bridge Close Bridge on the right bank (looking downstream). The wall will extend for approximately 70m.

For events greater than the 1 in 100, flood waters will overtop the flood defences causing damage to properties. The number of properties of each type that are at risk of flooding for events greater than the Q100 return period are the same as in Table 10.4. The number of properties used in the write-off calculation was based on the number of properties at risk for the 1 in 200 year return period event. The combined adopted losses for the properties for the Q100 scheme are summarised in Table 10.5.

10.3.4 Q200 Standard of Protection Damages

The scheme that offers at least a Q100 standard of protection to all properties is everything included within the Q50 scheme. However, the following changes are required:

- West Lane culvert, box culvert 1.4m x 2m,
- Channel widening downstream of West Lane culvert by 1.5m
- Beck Lane area embankment average height increased to 750mm,
- Rocks Lane Bridge embankment upstream average height increased to 500mm
- Rocks Lane Bridge embankment downstream average height increased to 650mm
- Floodwall upstream of Bridge Close average height increased to 1200mm,
- Floodwall downstream of Bridge Close average height increased to 1000mm,
- Caravan park embankment average height increased to 1500mm.

For events greater than 1 in 200 years, flood waters will overtop the flood defences causing damage to properties. The properties are at risk of flooding for events greater than the Q200 return period. The number of properties used in the write-off calculation was based on the number of properties at risk for the 1 in 200 year return period event. The combined adopted losses for the properties for the Q200 scheme are summarised in Table 10.5.

Table 10.5 – Adopted Loss Values for Option 3, for various Return Periods

Return Period	PV damages (£k)	Write-off value (£k)	Adopted Loss (£k)
Q25	2,696	3,361	2,696
Q50	1,929	3,361	1,929
Q100	941	3,361	941
Q200	338	3,361	338

10.4 Option 4

10.4.1 Q25 Standard of Protection Damages

With the exception of the flood embankment at the caravan park this option is the same as option 3 for a 1 in 25 year flood event. Improving the existing twin pipe culvert under West Lane with a 1metre by 0.9metre box culvert will be sufficient to provide a protect to all properties in the West Lane and Little Moor Drive area from the 1 in 25 year flood event. For the Beck Lane area construction of a flood embankment/floodwall for approximately 250m at an average height of 400mm is sufficient to protect all properties in this area from the 1 in 25 year flood event. In the Bridge Close area a floodwall would need to be constructed upstream of the bridge for approximately 60m and an average height of 400mm to provide this level of protection. At the caravan park raise caravans above the 1 in 25 year water level. For events greater than the 1 in 25, floodwaters will overtop the flood defences causing damage to properties. Table 10.4 summarises the number of properties that are at risk of flooding for events greater than the Q25 return period. The damage associated with each individual property for the various return periods are summarised in Appendix E.

10.4.2 Q50 Standard of Protection Damages

The scheme that offers at least a Q50 standard of protection to all properties is everything included within the Q25 scheme. However, the following changes are required:

- West Lane culvert, box culvert 1.2m by 1m,
- Beck Lane area embankment average height increased to 500mm,
- Floodwall at Bridge Close average height increased to 850mm,
- Raise Caravan floor levels above 1 in 50 year flood event.

In addition to these works, flood embankments are required downstream of Rocks Lane Bridge on both banks to an average height of 400mm. The left bank (looking downstream) will extend for approximately 75m and the right bank for approximately 150m.

For events greater than the 1 in 50 year, flood waters will overtop the flood defences causing damage to properties. The number of properties that are at risk of flooding for events greater than the Q50 return period are the same as in Table 10.4. The number of properties used in the write-off calculation was based on the number of properties at risk for the 1 in 200 year return period event. The combined adopted losses for the properties for the Q50 scheme are summarised in Table 10.5.

10.4.3 Q100 Standard of Protection Damages

The scheme that offers at least a Q100 standard of protection to all properties is everything included within the Q50 scheme. However, the following changes are required:

- West Lane culvert, box culvert 1.5m by 1.2m,
- Beck Lane area embankment average height increased to 600mm,
- Rocks Lane Bridge embankment downstream average height increased to 500mm
- Floodwall at Bridge Close average height increased to 1000mm,
- Raise Caravan floor levels above 1 in 100 year flood event.

In addition to these works, the channel downstream of West Lane culvert needs widening by 1m for approximately 120m, a flood embankment is required upstream of Rocks Lane Bridge on the left bank (looking downstream) to an average height of 500mm and a floodwall is required downstream of Bridge Close Bridge on the right bank (looking downstream). The wall will extend for approximately 70m.

For events greater than the 1 in 100, flood waters will overtop the flood defences causing damage to properties. The number of properties of each type that are at risk of flooding for events greater than the Q100 return period are the same as in Table 10.4. The number of properties used in the write-off calculation was based on the number of properties at risk for the 1 in 200 year return period event. The combined adopted losses for the properties for the Q100 scheme are summarised in Table 10.5.

10.4.4 Q200 Standard of Protection Damages

The scheme that offers at least a Q100 standard of protection to all properties is everything included within the Q50 scheme. However, the following changes are required:

- West Lane culvert, box culvert 1.4m by 2m,
- Channel widening downstream of West Lane culvert by 1.5m
- Beck Lane area embankment average height increased to 750mm,
- Rocks Lane Bridge embankment upstream average height increased to 500mm
- Rocks Lane Bridge embankment downstream average height increased to 650mm
- Floodwall upstream of Bridge Close average height increased to 1200mm,
- Floodwall downstream of Bridge Close average height increased to 1000mm,
- Raise Caravan floor levels above 1 in 100 year flood event.

For events greater than 1 in 200 years, flood waters will overtop the flood defences causing damage to properties. The properties are at risk of flooding for events greater than the Q200 return period. The number of properties used in the write-off calculation was based on the number of properties at risk for the 1 in 200 year return period event. The combined adopted losses for the properties for the Q200 scheme are summarised in Table 10.5.

10.5 Present Value Damages

The damages incurred are spread over the 50 year economic life of the project and discounted at a rate of 3.5% for the first 30 years and 3.0% after that, to give the present value damages incurred. These are summarised below in Table 10.6 for each of the options (full details of these calculations are provided in Appendix E). For the combined options various standards of protection (SoP) are considered.

Table 10.6 - Summary of Present Value Damages

	Options	Present Value Damages
Do Nothing		£3,877k
Do Minimum		£3,360k
Option 3 *Localised defences and improvements to structures including embankment at caravan park*	Q25 SoP	£2,696k
	Q50 SoP	£1,929k
	Q100 SoP	£941k
	Q200 SoP	£338k
Option 4 *Localised defences and improvements to structures including raising of caravans at caravan park*	Q25 SoP	£2,696k
	Q50 SoP	£1,929k
	Q100 SoP	£941k
	Q200 SoP	£338k

10.6 Loss of Life

The potential for the loss of human life during a flood event has not been considered explicitly in the assessment of ‘Do Nothing’ damages. However, it is thought that there is a risk to life if no action is taken, e.g. people being swept off their feet by flood water flowing along the roads. The behavioural characteristics of people during a flood are very unpredictable, so the risk to life is difficult to quantify. However, if loss of life was to be included in the economic analysis, the benefit cost ratio of each of the ‘Do Something’ options would increase as would the general priority of the scheme.

10.7 Traffic Disruption

Flooding from Cloughton Beck does affect West Lane, which is a stretch of the A171 road from Scarborough to Whitby. Due to the topography of the area, it is not envisaged that the flood water will pond on the road causing the road to be closed. Therefore, it is not anticipated that flooding of the road would lead to significant traffic disruption and costs associated with this have not been included.

10.8 Assessment of Risks

The risks associated with each scheme are summarised in Table 10.7. For option 3 the main risk is acquiring permission to flood the land and build the flood bund. Option 4 has more risks associated with it because it has the combined risks of option 3 and the additional risk of acquiring permission to continue to flood the caravan park, with only raising the caravan floor levels above the flood level.

Table 10.7 – Risks associated with the schemes for the two Combined Options

Risk	Option 3	Option 4
Permission required to enlarge culvert under A171	Yes	Yes
Permission to allow flooding of the caravan park	No	Yes
Environmental consents and additional investigations	Yes	Yes
Permission to construction a flood bund along the public footpath	Yes	Yes
Public consultation issues	Yes	Yes

11 Assessment of Costs

A breakdown of the estimated costs for each option is shown in Appendix F. Land purchase and compensation costs are covered separately along with any site investigation works required. Contingencies are assumed to be 25%. Due to the number of areas along the watercourse that require works the site set up, overheads and preliminaries have been assessed to be 35%.

Costs for each option are broken down into three components: capital (plus contingencies), maintenance and fees. The 'Do Minimum' improvements are also required for all the other options and so these costs are also incorporated into each option. For option 4 a compensation fee has been included for loss of access to the school field during flooding.

The costs incurred are then spread over the 50 year design life of the project and discounted (at a rate of 3.5% for the first 30 years and then 3.0% for the next 20 years) to give the present value costs incurred. These are in accordance with current Defra guidelines and are summarised below in Table 11.1. Full details of all the calculations are presented in Appendix F. The costs of the combined schemes are very similar but Option 4 has the lower costs associated with the higher return periods of Q100 and Q200.

Analysis of costs have been undertaken using CESMM3 (Civil Engineering Standard Method of Measurement, Martin Barnes, 1992) and experience from similar construction works. Assumptions regarding land purchase, site investigation costs and contingencies have been made and these will need to be checked.

Table 11.1. Summary of Present Value Option Costs for preferred scheme

<table>
<tr><th colspan="2">Option</th><th>Present Value of Costs (£k)</th></tr>
<tr><td colspan="2">Do Nothing</td><td>-</td></tr>
<tr><td colspan="2">Do Minimum (Maintenance)</td><td>31.5</td></tr>
<tr><td rowspan="4">Option 3

(Localised defences and improvements to structures including embankment at caravan park)</td><td>Q25 SoP</td><td>666.7</td></tr>
<tr><td>Q50 SoP</td><td>787.3</td></tr>
<tr><td>Q100 SoP</td><td>1,313.7</td></tr>
<tr><td>Q200 SoP</td><td>1,583.9</td></tr>
<tr><td rowspan="4">Option 4

(Localised defences and improvements to structures including raising of caravans at caravan park)</td><td>Q25 SoP</td><td>426.7</td></tr>
<tr><td>Q50 SoP</td><td>583.3</td></tr>
<tr><td>Q100 SoP</td><td>909.7</td></tr>
<tr><td>Q200 SoP</td><td>999.37</td></tr>
</table>

12 Benefit Cost Analysis

An incremental benefit cost analysis has been undertaken following the guidelines given in PAG3. Present value benefits are calculated by subtracting the present value 'Do Something' damages from the present value 'Do Nothing' damages. The benefit cost ratio is then calculated by dividing these benefits by the present value option costs.

Damages and costs have been estimated for all the options outlined in Section 8. Benefit cost ratios have, therefore, been estimated for each standard of protection. The results from this analysis are summarised in Table 12.1 for the PV Damages, and full details are provided in Appendix G.

From Table 12.1 it may be seen that the highest benefit cost ratio of 3.1 given by Option 4 with a Q200 standard of protection. This option also has the highest incremental benefit cost ratio. It can be seen that option 3 does not give a less favourable benefit cost ratio of 2.5 for a Q50 standard of protection.

Defra[1] have set up a priority scoring system which "attempts to ensure the equitable distribution of funding supporting the provision of flood and coastal defence solutions. It recognises that whilst it should be possible to undertake a broad brush economic analysis at an early stage in project development, it is not reasonable to undertake a full project appraisal. In addition to economics, it provides a simplified approach to weighting projects to take account of the intangible impacts on people and the natural environment." The calculations for the priority scoring for each of the schemes are in Appendix H and the scores for a Q200 standard of protection are summarised in Table 12.1.

[1] Defra Website – Annex B The Priority Scoring System

Table 12.1 - Summary of Incremental Benefit Cost Analysis for PV Damages

			Cost Benefis for Option 3 (Localised defences and improvements to structures including embankment at caravan park)				**Cost Benefis for Combined Option 4** (Localised defences and improvements to structures including raising of caravans at caravan park)			
	Do Nothing	Do Minimum	Q25 Standard of Protection	Q50 Standard of Protection	Q100 Standard of Protection	Q200 Standard of Protection	Q25 Standard of Protection	Q50 Standard of Protection	Q100 Standard of Protection	**Q200 Standard of Protection**
PV costs (PVc) (£k)	-	31.5	666.70	**787.3**	1,313.67	1,583.85	426.70	**583.30**	909.67	999.37
PV damage (PVd) (£k)	*3,876.6*	*3,359.93*	2,696.31	**1,929.78**	940.71	337.83	2,696.31	**1,843.13**	940.71	337.83
PV damage avoided (£k)	-	*516.67*	1,180.29	**1,946.82**	2,935.89	3,538.76	1,180.29	**2,033.47**	2,935.89	3,538.76
Total PV benefits (PVb) (£k)	-	516.67	1,180.29	**1,946.82**	2,935.89	3,540.76	1,180.29	**2,033.47**	2,936.89	3,540.76
Net Present Value (NPV) (£k)	-	485.17	513.59	**1,159.52**	1,623.22	1,956.92	753.59	**1,450.16**	2,027.22	2,541.40
Average Benefit/Cost Ratio	-	16.4	1.8	**2.5**	2.2	2.2	2.8	**3.5**	3.2	3.5
Incremental Benefit/Cost Ratio	-	-	1.0	**6.4**	1.9	2.2	1.7	**5.5**	2.8	6.7
Defra Priority Score	-	-	-	**12**	-	-	-	**16**	-	-

13 Conclusions & Recommendations

An in-depth options assessment and hydraulic modelling study has been undertaken to determine the causes, extents and frequency of flooding in the Burniston Beck catchment, including the tributaries of Cloughton and Quarry Becks. Mitigation options have been assessed and costed and the following conclusions determined.

13.1 Flooding causes, extents and mechanisms

(i) Flooding within the properties at a number of points along the watercourses is reasonably frequent and extensive and justifies the designation of Burniston and Cloughton Becks as Critical Ordinary Watercourses.

(ii) Hydraulic modelling predicts that flooding is first experienced by 8 properties for a 1 in 10 year return period, at West Lane. This rises to 14 properties for the 25 year event and 69 properties for the 200 year event. Flood depths of up to 0.6m are predicted for some properties for the 1 in 200 year event.

(iii) There are four main stretches of flooding and specific flooding mechanisms associated with these areas as summarised below:

1	West Lane and Little Moor Drive Area (27 properties affected)	Limited capacity of the of culvert under West Lane causing overtopping (Flooding starts at a return period of 10 years)
2	Church Beck Cottages and Beck Lane (19 properties affected)	Limited channel capacity causing poor channel conveyance (Flooding starts at a return period of 25 years)
3	Rocks Lane, Bridge Close and Coastal Rd (23 properties affected)	Limited channel capacity and structures restricting flow (Flooding starts at a return period of 25 years)
4	Caravan Park	Limited channel capacity causing poor channel conveyance (Flooding starts at a return period of 25 years)

13.2 Preferred flood mitigation option

A number of mitigation measures were assessed, tested and costed. Option 4 (200 year protection) is the preferred scheme (localised flood defence structures, channel, widening and culvert improvements) based on the higher cost benefit ratio (3.1 calculated) and the fewer perceived risks associated with the scheme. This scheme mitigates flooding by the construction of flood embankments and walls, raising the caravans above flood levels, widening of the existing channel for approximately 120m of West Lane culvert and improvements to the West Lane culvert.

The preferred option (option 4) is summarised below.

Protecting properties West Lane and Little Moor Driver Area

(i) Improve West Lane culvert to a box culvert 1.4m by 2m

(ii) Channel widening downstream of West Lane culvert by 1.5m for 120m

Protecting Properties Church Beck Cottages and Beck Lane Area

(i) Construction a flood embankment average height 750mm for 250m

Protecting properties Rocks Lane and Bridge Close

(iii) Embankment upstream of Rocks Lane Bridge for 30m average 500mm

(iv) Embankment downstream Rocks Lane Bridge average height 650mm, right bank 150m and left bank 75m

(v) Floodwall upstream of Bridge Close average height 1200mm for 60m

(i) Floodwall downstream of Bridge Close average height 1000mm for 70m

Protecting Caravan Park

(i) Raise Caravans above 1 in 200 year flood event

Maintenance Measures

(iii) The structures are frequently inspected for debris and any trash screens cleaned along the watercourses. These should also be designed to be accessed and cleaned during flood conditions.

(iv) The channel vegetation and debris is required to be kept 'under control' to assist in maximising the channel capacity.

13.3 Consideration of risks

The main ecological risks are associated with the presence of otters along Burniston Beck and the possible presence of badgers and bats. Licenses, and close consultations with Defra and English Nature will be required for the development of any proposals.

13.4 Recommendations

(viii) Burniston and Cloughton Becks are considered to be critical ordinary watercourses and this status should be maintained.

(ix) In terms of the selection of freeboard and factors of safety regarding channel design, a manning's n of 0.08 (to simulate a highly vegetated channel) increased water levels of 100-200mm for the 100 year design event. It is recommended that this robustness should be accommodated for in the design as freeboard and a minimum 300mm should be allowed for.

(x) This Project Appraisal Report has revealed that there is a strong economic case to advance this project and present it to Defra for grant aid assistance with a benefit cost ratio of 3.1.

(xi) As part of the detailed design phase, a comprehensive site investigation would be required. This will consist of a full services search, and relevant boreholes to determine ground conditions. This will enable a greater level of confidence to be placed in the scheme costs which could then be revisited. The issue of permission to do works on land will also need to be further investigated.

(xii) The progression of this study will need to incorporate a carefully designed consultation strategy to ensure that all stakeholder comments, aspirations and opportunities are maximised.

(xiii) It is recommended that consideration be given to local rainfall and water level monitoring such that a calibration of the hydraulic model can be undertaken at a future date. However, it is not suggested that the project is delayed for this requirement.

(xiv) It is recommended that the area be flown to obtain LiDAR data. This will help improve the accuracy of the flood outlines.