Knowledge of, and response to, upland flash flooding: a case study of flood risk management of the 2005 flash flood in upper Ryedale, North Yorkshire, U.K.

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Jonathan Hopkins

The dangerous hazard posed by flash flooding to upland communities is likely to increase due to climate change. The flood risk management policy approach has become predominant since the 1990s, with an emphasis on the public awareness of, and responses to, flood risks; however, the unpredictable nature of upland flash flooding means that responses to such hazards are uncertain. This thesis uses an integrated analysis of social and physical science datasets to study responses by local residents and the Environment Agency to flash flooding, using a case study of a major upland flood in North Yorkshire.

Responses to flash flooding within upland communities were found to be mostly present as changes to individual behaviour and awareness. However, physical, damage reducing modifications were limited. Flash flood hazard perception was found to be linked to knowledge and experience of local flooding. Major flash flood events occurring in areas which have not experienced other recent floods are unlikely to increase perceptions or provoke responses. Although local awareness of changing weather patterns was found, supporting analyses of rainfall records, local flood risks were frequently framed in the context of river management, rather than climate change.

The implementation of policy changes and responses to flash flooding by the Environment Agency will prove difficult at the local level, due to the nature of attitudes and perceptions encountered at the local level, including important differences in the perception of the flash flood hazard between local residents and representatives from nationwide organisations. Encouraging property-level modifications following flash floods, in accordance with national policies, is very difficult. In order to increase local perceptions of the flash flood hazard, the use of participatory work, focusing on long-term awareness raising and the sharing of locally held flood knowledge may be beneficial, alongside the support of existing resilience in upland communities.

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Declaration

I confirm that no part of the material presented in this thesis has previously been submitted by me or any other person for a degree in this or any other university. In all cases, where it is relevant, material from the work of others has been acknowledged.

Statement of Copyright

Jonathan Hopkins

20th May 2012

Acknowledgements

A number of people have helped me over the course of this research project, and I am going to try to cover them here. I first of all acknowledge the ESRC/NERC +3 award (reference number: ES/F00980/1) which provided funding for this work. I must give huge thanks to my supervisors Jeff Warburton, Danny Donoghue and Ray Hudson for their advice, support and encouragement over the course of the PhD, in particular my former Masters supervisor and good friend Jeff. In terms of practical help with research, I must give thanks to the Design and Imaging unit in the Geography Department for their help with printing, as well as the reception staff who helped me immensely with posting questionnaires. I would like to thank Rob Dunford for his help with ArcGIS, and Tim Burt for much guidance on the formation and analysis of rainfall records. I must thank all those who let me interview them: the residents of Helmsley, Rievaulx and Hawnby in North Yorkshire and the representatives from the Environment Agency and Ryedale District Council, all I hope is that this thesis constitutes a fair and reasonable assessment of the information that was collected. I'd like to thank the Environment Agency for the provision of data, and all other data received over the course of this thesis (rainfall data, photographs and questionnaires) was extremely gratefully received. Away from the PhD, sport has been a nice distraction and I've enjoyed playing for Ustinov Pool Team, Durham Staff Cricket Club and Belmont Cricket Club at various times, and greatly enjoyed the Friday afternoon kickabouts down at Maiden Castle. And lastly, but most of all, I'd like to thank my mother (Janet) and father (Bob) for their love, support and help over the duration of this thesis.

For Mum

Chapter 1

Introduction

This introduction provides a summary of the research context in which this thesis is placed. The first three sections constitute a review of research and literature on flooding and flash flooding. After briefly assessing the flood hazard and its impacts on the United Kingdom as a whole (Section 1.1) the upland flash flood hazard and the challenges it presents for management are detailed in Section 1.2. Section 1.3 then discusses the nature of managing flash flood events, and relevant flood policies and strategies. Section 1.4 distils the information presented in the first three sections and outlines the resulting research needs, and the thesis aim and objectives. Section 1.5 introduces the case study used to research the thesis objectives: the flash flood event in upper Ryedale, North Yorkshire which occurred on the 19th June 2005.

1.1 Flooding in the U.K.

A flood is defined as "an overflow of a large amount of water over dry land" (Stevenson et al., 2002: 268). Flooding is an extremely serious hazard, and "...in most parts of the world, flooding is the leading cause of losses due to natural phenomena" (Kron, 2009: 68). The Environment Agency assesses that 5.2 million properties (1 in 6) in England are at risk of flooding, with flooding from rivers and the sea alone estimated to cause annual damages of £1 billion to 2.4 million properties (Environment Agency, 2009*a*). Since the 1990s, the U.K. has observed a number of major flood events, including major regional flooding affecting northern England, in Cumbria (2005 and 2009) (Environment Agency, 2006*a*; British Broadcasting Corporation News, 2009) and in North Yorkshire (1999) (Environment Agency, 2007*a*) (key flooded locations of Carlisle, Cockermouth and Malton shown on Figure 1.1). Widespread, predominantly lowland flooding occurred across the U.K. in 1998 (Horner and Walsh, 2000), 2000 (Marsh, 2001) and in 2007 (Marsh and Hannaford, 2007). Heavy, localised rainfall has caused major flash floods in Boscastle, Cornwall (2004) (Burt, 2005), upper Ryedale, North Yorkshire (2005) (Wass et al., 2008) and Alston, Cumbria (2007) (Cumberland and Westmorland Herald, 2007) (Figure 1.1). Therefore, flooding in the U.K. is becoming increasingly unpredictable, as a result of (uncertain) changes to climate (Wheater, 2006), and research attempting to place recent major floods in the context of climate change has been carried out (Lamb, 2001; Marsh and Hannaford, 2007; Lane, 2008). Additionally, it is accepted that the recent high frequency of flood events have constituted a 'flood rich' period (Robson et al., 1998; Lane, 2008), providing challenges in flood management and responses at institutional and household levels. Additionally, certain types of flood, including upland flash floods, pose a particularly unpredictable and dangerous hazard (Section 1.2).

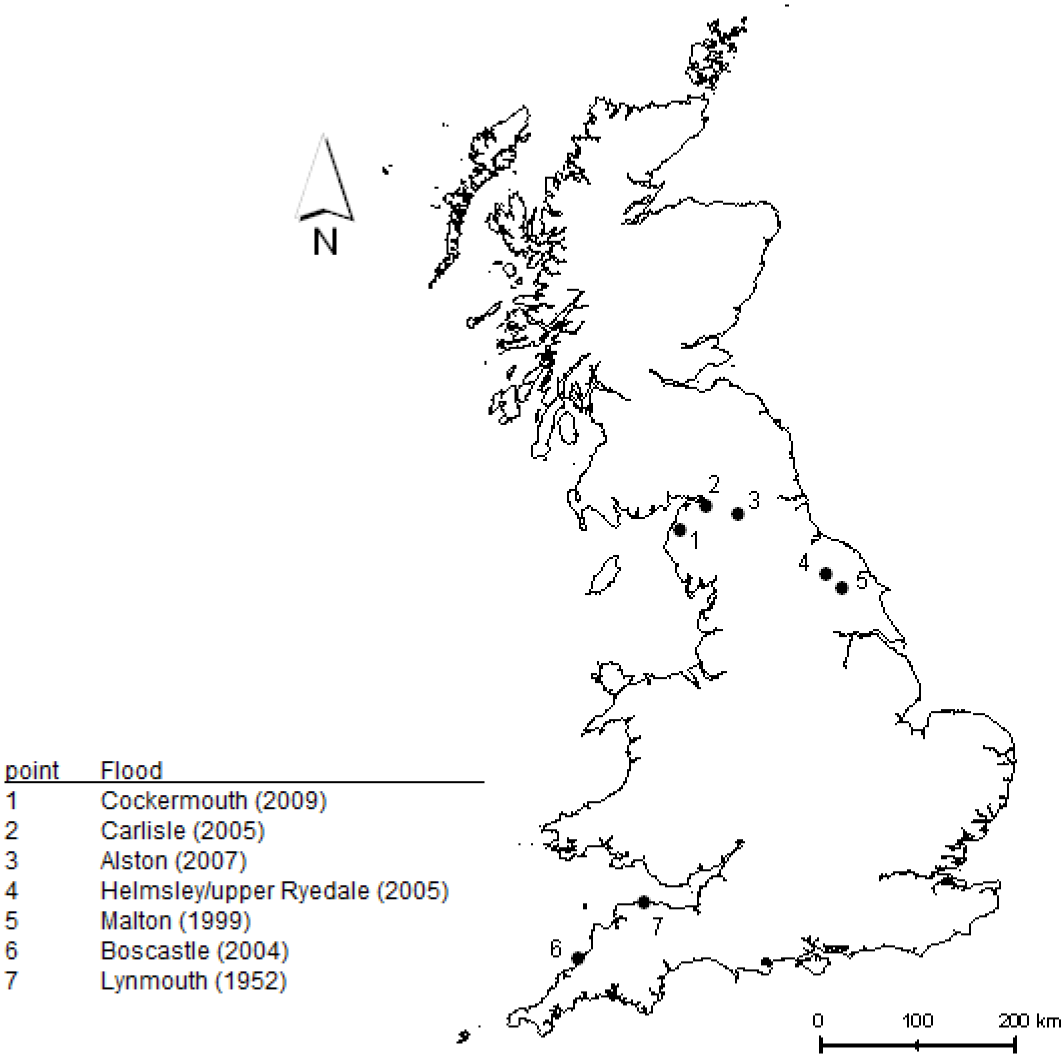


Figure 1.1: Large flood events in England (flash floods, and localised floods) mentioned during this chapter, also showing the flash flood in Helmsley and upper Ryedale in 2005 which is the subject of this thesis. Diagram contains Ordnance Survey Strategi® data: © Crown Copyright/database right 2011. An Ordnance Survey/EDINA supplied service.

1.2 The upland flash flood hazard

There are many definitions of what a 'flash flood' is, based upon timing, flood appearance and location (Gruntfest and Huber, 1991), however an appropriate definition is "...floods which are characterised by their rapid occurrence resulting in a very limited opportunity for warnings to be prepared and issued" (Collier, 2007: 3).

Similarly, there is no standardised definition of what constitutes an 'upland' area. Definitions based purely on altitude are regarded as too simplistic, due to variations in land use and vegetation (Backshall and Rebane, 2001). Other definitions based upon land use can also be made: Ratcliffe and Thompson (1988) stated that hill pastures, moorlands and mountains account for c. 30% of land in England, this being close to the definition of 'Less Favoured Areas' established by the European Union in 1975 (Backshall and Rebane, 2001). The Foresight Future Flooding project meanwhile used a definition based upon the presence of steep valley slopes (Evans et al., 2004) which showed that upland catchments are distributed mainly in the north of England, Wales and south-west England. This latter definition is most useful for a study of flooding, as the form of a catchment area (including its gradient and altitude) and further factors (including soil types and moisture content) strongly influence the speed of surface runoff (Newson, 1994). Rapid surface runoff is favoured in catchments that are steep, have high soil moisture levels, have low water storage capacities and infiltration rates, and provide few or no obstacles to surface runoff (Robinson and Rycroft, 1999; Kelsch et al., 2001; Collier et al., 2002). The faster response of upland rivers to rainfall events (compared with that of lowland rivers) results from key differences between upland and lowland catchments, as described by Knapp (1979):

- Higher rainfall totals in upland areas, and wetter soils.
- Steeper upland slopes, causing quicker runoff.
- Lack of upland water storage (due to small floodplains), causing the confinement of floodwaters.

These factors mean that steep-sided upland catchments are ‘naturally’ flashier than lowland catchments (Knapp, 1979), and have an associated higher risk of flash floods. In lowland areas, considerable storage capacity exists and the attenuation of flood peaks reduces the overall response time of a flood event (Kelsch et al., 2001; Mayes et al., 2006). For these reasons, flash floods are very different in character to lowland flood events (Bronstert et al., 2002; Bronstert, 2003; Table 1.1).

	Plain/lowland flood	Flash flood
Timescale	Long-lasting	Short-lived
Size/type of catchment affected	Large, lowland	Small, often mountainous
Rainfall	Persistent heavy rainfall over a widespread area, snowmelt	Short, intense, localised downpours or thunderstorms
Main mechanism of flooding	Overtopping of river banks	Rapid runoff of water from hillslopes
'Lag time' between rainfall event and river flow rise	Long	Short

Table 1.1: Generalised characteristics of plain (or lowland) and flash flood events. Some information in table adapted from Bronstert et al. (2002), page 510.

Rainfall intensity is the most important factor in the formation of, and severity of, flash floods (Gruntfest and Huber, 1991; Doswell et al., 1996; Kelsch et al., 2001). This again constitutes a contrast with lowland floods, which tend to happen due to widespread rainfall events occurring over a large spatial area for a long time, however flash floods occur as a result of smaller scale rainfall systems (frequently very localised thunderstorms) that can last only a few hours, or less (Hirschboeck et al., 2000). These extreme rainfall events have a tendency to occur in the summer as a result of high temperatures leading to convection (Kelsch et al., 2001; Collier et al., 2002; Merz and Blöschl, 2003; Hand et al., 2004; Rodda et al., 2009). For instance, Archer (1992) listed 53 flash flood events which have occurred in north-east England: of these, 40 floods had occurred in the summer months of June, July and August. Examples of such events include the upper Ryedale flash flood that comprises the case study focus of this thesis (Wass et al., 2008), the flash flood in Boscastle, Cornwall in 2004 (Burt, 2005), the very large flash flood that occurred at Lynmouth in 1952 (Joint, 2008; Figure 1.1), and a number of upland flash flood events in

Lancashire (Duckworth and Seed, 1969) and the northern Pennines (Carling, 1986; Harvey, 1986; Acreman, 1989; Cumberland and Westmorland Herald, 2007) (Alston flood shown in Figure 1.1).

The dangers posed by flash flood events arise directly from their characteristics. Globally, flash floods are one of the most dangerous natural hazard phenomena that exists (Bonacci et al., 2006; Knocke and Kolivras, 2007). Gruntfest and Handmer (2001, adapted from page 4) have outlined the main reasons why flash floods provide a threat:

- They occur suddenly and unpredictably, giving very little opportunity for the communication of warnings to those at risk.
- Floodwaters are fast moving, presenting a severe danger to people and a strong probability of physical damage to buildings and infrastructure.
- Flash floods are rare and short-lived, meaning that providing outside/emergency help and assistance during the flood event is very difficult, and such help usually arrives after the flood.

Loss of life in flood events is strongly linked to the velocity of floodwaters, the speed of flood onset, and the presence (or not) of a warning (Ramsbottom et al., 2003; Penning-Rowsell et al., 2005), making flash floods particularly dangerous (Cave et al., 2009). An article published in 2007 stated that "...it would be over optimistic to expect the reliable spatially accurate quantitative prediction of flash floods to extend beyond 1 or 2 hours ahead within the next 10 years" (Collier, 2007: 19). A further review paper published in 2011 stated that flash flood lead times had reached six hours (Hapuarachchi et al., 2011), although "...further improvements in lead-time (12-24h) and accuracy of QPFs (quantitative precipitation forecasts) is essential... for providing meaningful flash flood forecasts" (Hapuarachchi et al., 2011: 2781). Providing early warnings for flash floods has been described as being “...among the most challenging topics in the scientific research in hydrometeorology” (Alfieri et al., 2011: 69). Crucially, in sudden-onset flash floods, lower numbers of residents are able to be warned and/or receive information about occurring flood events, when compared with slow-rise floods (Steinführer and Kuhlicke, 2007). The dangers posed by flash floods, in a U.K. context, have become apparent as the flash flood threat has increased in recent years following a number of flash flood events:

> “The UK has recently experienced a number of flash floods, such as those that occurred in Boscastle in 2004 and Helmsley in 2005. Flash floods are characterised by very short times between rainfall and subsequent flooding. They can also present an extreme danger to life, property and infrastructure because of the suddenness in the rise in water level, the flow velocity and debris. Predicting, preparing for and responding to flash floods poses great challenges.”
>
> Cave et al., 2009: iv

Carrying out research into flash flooding is challenging. Despite the threat that they pose, the understanding of flash floods is low, as they often occur in ungauged catchments (Gaume et al., 2004; 2009). An additional difficulty in studying upland flooding in general is the low availability of river flow data from these areas (McEwen, 1987; Macklin and Rumsby, 2007); additionally, few long upland rainfall records exist in the U.K. (Burt and Ferranti, 2012). For example, a study of 25 extreme European flash flood events found that around half of the events were not documented by discharge data (Marchi et al., 2010). The physical monitoring of flash floods is extremely difficult, as they “...develop at space and time scales that conventional observation systems of rain and discharge in rivers are not able to monitor. As these events are locally rare, they also escape the realm of field-based experiments” (Creutin and Borga, 2003: 1453), although a collection of data from several European flash floods has been compiled (Gaume et al., 2009).

Due to these reasons, some studies have suggested that flash floods should be regarded as a distinct type of hazard, separately from lowland flooding (Rosenthal and Bezuyen, 2000) with the suggestion that there is a need to manage hazards from flash floods in a distinct manner to traditional floods as “The solutions developed for the management of river floods do not prove effective in dealing with flash floods, which require separate means” (Associated Programme on Flood Management, 2007: 19). Because of the scale and nature of the hazard, “...flash floods are best managed by the local authorities with active and effective involvement of the people at risk” (Associated Programme on Flood Management, 2007: 59). Creutin et al. (2009) found that local responses to flooding, rather than institutional responses, dominate in smaller catchments. With regards to responses to flooding, the mitigation of lowland floods typically concerns the prevention and reduction of damage to property, but the main objective of flash flood responses should be to prevent the loss of life (Gruntfest and Huber, 1991). The danger which flash flood events present to communities and livelihoods is clear from flash flood events at the European level: in France, flash flood events caused the deaths of over 100 people and over €1 billion damages in the country over two decades to 2004 (Gaume et al., 2004). This includes two major flash floods in south-east France in 1999 and 2002 which between them caused 58 deaths and damages of €771 million and €1,530 million, respectively (Vinet, 2008). In the Barcelona area of Spain, a flash flood in 1962 caused over 815 deaths (Llasat et al., 2009). In the U.K., flash flood events tend to be much smaller in scale, however, the largest flash flood event in the U.K. (that at Lynmouth in 1952, Figure 1.1) caused 34 deaths and destroyed 39 buildings (Joint, 2008). Of the two largest, most recent flash flood events, the flooding at Boscastle in 2004 caused flooding in over 70 properties, with over 130 people having to be winched to safety by helicopter (Burt, 2005); while at upper Ryedale in 2005, total storm damages totalled £9.5 million

(Wass et al., 2008, including neighbouring catchments), and 32 properties suffered flood damage in upper Ryedale itself (Wass et al., 2008). These flash flood events have occurred with the background of a projected increase in flash flood risks in the U.K. and Europe. The International Panel on Climate Change's Fourth Assessment Report in 2007 summarised that "...flash floods are likely to increase throughout Europe" (Alcamo et al., 2007: 543). The impacts of climate change are likely to cause shifts in seasonal precipitation totals and heavy rainfall in the U.K. (Fowler and Ekström, 2009; Murphy et al., 2009); globally, those areas where flooding from intense summer rainfall occurs are likely to see an increase in intense precipitation (Kundzewicz et al., 2010). The increasing threat of flash flooding was recognised by Sir David King, the (former) chief scientific adviser to the U.K. Government, who stated in 2007 that "The most serious impact (of climate change) in Britain is flash floods" (quoted in Weaver, 2007). Non-fluvial floods, including pluvial, drainage and groundwater flooding, are also driven by an increased intensity of summer thunderstorms (Hankin et al., 2008).

Despite the danger posed by flash floods, a number of challenges exist in the response to flash flood events at the individual/community and institutional levels. A major issue is the fact that flash flood events are rare (Gruntfest and Handmer, 2001; Creutin and Borga, 2003; Borga et al., 2008) and public understanding and knowledge of flash flood events and their risks tends to be poor as a result (Knocke and Kolivras, 2007). The fundamental difficulty in preparing for flash flood events, and the reason why they are so threatening, is summarised in the view of Burn (1999) that "...the flood events that require the greatest level of preparation and response are very rare" (Burn, 1999: 3452). Montz and Gruntfest (2002) also summarised the issue: "Because such events (flash floods) usually come as surprises, warning and preparation are essential; however, because they are rare, the motivation to invest time and resources into such activities is low" (Montz and

Gruntfest, 2002: 16). Across wider upland areas, flash floods are more frequent (Carling, 1986; McEwen and Werritty, 1988). Flash floods represent only one of a number of climate/weather-influenced hazards which can affect upland areas. Shallow landslides can deliver large volumes of sediment to stream channels (Warburton et al., 2008). Erosion and landslide events have led to the closure of trunk roads in upland areas of England (Johnson and Warburton, 2002; Boon and Evans, 2008) and Scotland (Winter et al., 2008*a*). In the latter events (in 2004), three trunk roads were affected and at one location, 57 people were airlifted after becoming stuck between debris flows (Winter et al., 2008*a*); other landslides have also taken place on the Scottish road network since, and a study of these landslides suggested that "Such events should not be seen as isolated occurrences" (Winter et al., 2008*b*: 9). Further upland hazards are temperature-driven: during the severe winter of 2009-2010 across the U.K., upland areas saw the longest duration of snow cover (Prior and Kendon, 2011).

In addition to the greater susceptibility of upland areas to these hazards, there are additional vulnerabilities experienced by populations of upland areas, including remoteness from services, reliance upon private transport, lack of amenities in smaller settlements, and lower incomes from farming than in lowland areas; although upland communities are also viewed as self-reliant and supportive (Department for the Environment, Food and Rural Affairs, 2011*a*). Conversely, research in mountain communities in Italy found that local knowledge, relevant to effective hazard response, had been lost (De Marchi et al., 2007; Steinführer et al., 2009). Rural, remote areas are less accessible and also depend upon infrastructure, including roads and bridges, for access following floods (Vinet, 2008): flood responses are hindered if these roads are flooded (Versini et al., 2010). Also the small, distributed populations of rural areas mean that losses per individual tend to be high (Vinet, 2008).

1.3 Flash floods and the wider flood risk management context

The difficulty of responding to flash flood events can be placed in the context of changes to flood policies in England and Wales and Europe since the 1990s, which show a steady shift from policies which aim to defend against flooding to those which are best described as flood risk management (Sayers et al., 2002; Tunstall et al., 2004; Johnson et al., 2005; Penning-Rowsell et al., 2006; Merz et al., 2010). Existing flood defence policies were questioned "...in the light of climate change and floodplain development pressures" (Brown and Damery, 2002: 412). Additionally, increasing exposure to flooding places pressure on the existing system: across Europe, increased vulnerability and exposure to flooding is the main driver of increasing flood losses since the 1970s (resulting from population growth, increases in material wealth, and human changes to hydrological systems) (Mitchell, 2003; Barredo, 2009).

Exposure to flooding, and the costs of flooding are expected to increase significantly by 2080 in the U.K. as the result of a number of physical, socio-economic, management and policy drivers (Evans et al., 2004, 2008); with similar predictions made for Europe as a whole (Ciscar et al., 2009). Globally, the design of water management systems has assumed stationarity in natural systems (whereby the probabilities of river flow are not changing over time); this is challenged by climate changes and continuing human influence in river basins (Milly et al., 2008) and present and future non-stationarity in flood risk (Wheater, 2006). Changes to future flood risks are uncertain (Kundzewicz et al., 2010; Merz et al., 2010). In the U.K., changes to a wetter, more extreme rainfall regime are suggested by changes to observed rainfall intensities (e.g. Maraun et al., 2008), and projections of more extreme winter rainfall in the future (Fowler and Ekström, 2009; Murphy et al., 2009) and Europe has also observed an increase in the frequency of intense precipitation events as a whole (Kundzewicz et al., 2010). Therefore, there is a need for a greater compromise between flood defence engineering and environmental concerns (Institution of Civil Engineers, 2001) as the use of flood defences alone is not sustainable (Brown and Damery, 2002; Borrows, 2006); as well as a need to “...live with rivers” (to quote part of the title of the Institution of Civil Engineers’ report (2001)). Therefore, the aim of flood risk management is to manage "...whole flooding systems, be they catchments or coastlines, in an integrated way that accounts for all of the potential interventions that may alter flood risk" (Sayers et al., 2002: 37). A long-term approach, taking into account the vulnerability and exposure of populations to flooding, as well as perceptions of flood risk, is now favoured (Brown and Damery, 2002).

This approach towards flood risk management has been observed in recent policies to deal with flood risks. In 2004 the Making space for water strategy for England was introduced by the Government (Department for the Environment, Food and Rural Affairs (hence: DEFRA), 2005). Further strategy documents include Future Water (DEFRA, 2008*a*) and a strategy for flood and coastal erosion risks (DEFRA, 2011*b*). The Government response to Making space for water (DEFRA, 2005) described a ‘Vision’ of future risk management in England following the strategy. Key aspects of this strategy included the importance of sustainable development: “The concept of sustainable development will be firmly rooted in all flood risk management and coastal erosion decisions and operations” (page 14) and the encouragement of local involvement: “...there will be local participation in decision-making, in particular through the preparation of Catchment Flood Management Plans and Shoreline Management Plans, within a context of national standards and nationwide information on flood risks and prioritisation” (page 15). Crucially, the need to accept some flooding in areas where flood defences were not justifiable was noted (DEFRA, 2005). Additionally, the strategy identified the importance of improving resilience to flooding at the local level, as well as the importance of raising awareness and preparation for flood risks:

> "An important aspect of making communities on the floodplain more sustainable will be to make buildings more resilient to flooding. In general, incorporating resilience and resistance should ensure that properties recover more quickly than they would otherwise following a flood event, helping to minimise time out of the building for owners, stress and health problems, and repair costs. In the case of isolated or small rural communities, which are unlikely to benefit from a community scheme, building resilience or resistance may represent a key tool for managing their risk."
>
> DEFRA, 2005: 23
>
> "There is a fairly wide consensus on the need to raise awareness and preparation within communities for the changing flood and erosion risks resulting from climate change. Community partnerships were seen as very effective, and their wider development would be welcomed. Opportunities to educate the next generation about flood and erosion risks were also seen as important."
>
> DEFRA, 2005: 35

This strategy has been followed with reform of planning regulations (Department for Communities and Local Government, 2006), which aim to prevent development in areas subject to flooding. During the summer of 2007, widespread flooding in England and Wales (Marsh and Hannaford, 2007) led to a major review of the flood response system across the country. Importantly, the review recommended changes to the role of the Environment Agency (Pitt, 2008: Recommendation 2) and for local flood risk to be managed by local authorities (Recommendation 14), as well as the recognition of the need to improve warnings and forecasting for types of flooding other than 'traditional' flooding, including surface water flooding and flooding caused by extreme rainfall (Pitt, 2008). Additionally, the review recommended the use of property-level mitigation measures aimed at increasing resilience and resistance:

> “Property-level resistance and resilience can also help minimise damage from floodwaters. Resistance measures are aimed at keeping water out of buildings, or at least minimising the amount that enters by the use of barriers such as door guards to seal entry points. Resilience measures are aimed at minimising the damage when a building is flooding, thereby facilitating the quickest possible recovery.”
>
> Pitt, 2008: Executive Summary: xv

Many of the findings of the Pitt Review (2008) were recognised also in a separate report of the House of Commons Environment, Food and Rural Affairs Committee, 'Flooding'. The report described the system for the management of surface water flood risks as "...unclear and chaotic" (Environment, Food and Rural Affairs Committee, 2008: 15). This report also recognised the need to increase public awareness of flood risks, by greater engagement between the public and the Environment Agency (Environment, Food and Rural Affairs Committee, 2008). The Environment Agency’s corporate strategy for 2010-2015 mentions a commitment to “...work to protect people from environmental risks, including flooding, and work within communities to develop shared solutions” (Environment Agency, 2009*b*: 19). The strategy of flood and coastal erosion risk management for England presented to Parliament (2011) mentions the key aim of "...increasing public awareness of the risk... and engaging with people at risk to encourage them to take action to manage the risks that they face and to make their property more resilient" (DEFRA, 2011*b*: 14), an aim which continues some of the key themes detailed above.

It is notable that, at the European level, similar policy changes have occurred, with a general shift from flood prevention to flood risk management, and major flood events (the Danube and Elbe floods in 2002) led to an increased awareness of the impacts of climate change in Europe (Vogel, 2002) and also led to policy changes (Mostert and Junier, 2009). The Flood Risk Directive (Directive 2007/60/EC of the European Parliament and of the Council, 2007) is the most significant flood policy development passed by the European Union and its provisions represent, and underpin, the principle of flood risk management. The Directive requires member states to carry out flood assessments (Directive 2007/60/EC, 2007: Chapter II, Article 4) and identify areas where flood risks exist or may occur (Chapter II, Article 5(1)). In these areas, flood risk and flood hazard maps, showing the extent of a range of different probability floods, must be produced (Directive 2007/60/EC, 2007: Chapter III, Article 6). Then Flood Risk Management Plans are to be produced, which "...shall address all aspects of flood risk management focusing on prevention, protection, preparedness, including flood forecasts and early warning systems and taking into account the characteristics of the particular river basin or sub-basin" (Directive 2007/60/EC, 2007: Chapter IV, Article 7(3): 31). The principles of this directive have clear implications for a more localised management of flood risks, and a move away from hard flood defences: information about flood risks should be made publicly available (Directive 2007/60/EC, 2007: Chapter V, Article 10(1)), and flood risk management plans should be created with the "...active involvement of interested parties" (Chapter V, Article 10(2): 32). Additionally, flood risks in areas with sparse populations (e.g. rural areas) "...could be considered not to be significant" (Directive 2007/60/EC, 2007: (11): 28), and flood risk management plans should have "...a view to (give) rivers more space" (Directive 2007/60/EC, 2007: (14): 28): such plans may involve accepting some controlled flooding (Chapter IV, Article 7(3)).

The concept of flood preparedness, and its social, technical, institutional, and economic dimensions, is therefore central to flood risk management (Raaijmakers et al., 2008). Research in the U.K. shows that temporary household measures (flood guards, airbrick covers) can significantly reduce flood damage costs (by c. 50%), with further permanent measures preventing 65-84% of damage (Thurston et al., 2008). Flood-adapted interior fittings were also found to reduce building and contents losses by 53% in a study on the River Elbe in Dresden, Germany (Kreibich et al., 2005; Kreibich and Thieken, 2009); in these studies, an increase in preparedness occurred after a large flood event. While potential flood damage represents a combination of flood exposure and flood sensitivity, actual flood damage is strongly influenced by precautionary measures and adaptations (Grothmann and Reusswig, 2006).

The shift to a paradigm of flood risk management means, in addition, a shift in the responsibility for responses to flooding, with greater responsibility placed upon the public's shoulders (White et al., 2010) and communities given a “...greater responsibility for managing their own risks” (DEFRA, 2011*b*: 14) Residents at risk of flooding are now expected to be aware of the flood hazard, engage in the management process and make adaptations themselves, replacing the traditional responsibility of the government for flood protection (Penning-Rowsell et al., 2006; Steinführer and Kuhlicke, 2007). However, some studies have shown that those at risk do not take on this responsibility, with a gap in knowledge between experts and local perspectives apparent, alongside a continuing public belief in traditional schemes of structural responses and government responsibility for dealing with flooding (Steinführer and Kuhlicke, 2007). The lack of flood awareness and action among U.K. residents was acknowledged in 2005 by the then Chief Executive of the Environment Agency, Baroness Young, who stated: "There's a tendency for people to think 'it'll never happen to me'. The fact is, it could, we just don't know when. People in this country cannot afford to be complacent about flood risk" (quoted in Osborne (and agencies), 2005). In 2005, the Environment Agency estimated that two fifths (41%) of those at risk of flooding in England and Wales were not aware of the risk (Osborne (and agencies), 2005). Borrows (2006) claimed that U.K. flood managers have come across a number of views and attitudes which make it difficult to increase awareness and mitigation. Informing the public about risks (in general) is difficult, due to the complex, uncertain nature of information, and public perceptions (Slovic et al., 1981). With regard to property-level flood mitigation measures, a survey of U.K. households and businesses at risk of flooding suggested that while majorities of householders surveyed agreed that household mitigation measures would "...decrease the disruption if there was a flood", "...make me feel safer" and "...save me money in the long term" (adapted and quoted from table 4, Thurston et al., 2008: 12), large numbers believed that these responses were too expensive (57% of households) and only 27% of flooded households had taken protective action (Thurston et al., 2008). Similarly, a survey of individuals affected by the (predominantly lowland) summer flooding in England and Wales in 2007 found that over eight out of ten individuals living in flood-hit areas "...believe there is nothing they can do to protect their home from flooding", with 95% of those living in flood-hit areas taking no measures whatsoever to reduce the risk of future damage; this was "...despite the fact that nearly half (43%) of those affected... say their fear of flooding has increased" (adapted and quoted from Norwich Union, 2008). De Marchi et al. (2007) found that flash flooding in Italy led to extremely few protective measures being taken by residents. Although the lack of response to flood risk is extremely important for potential future damages, research on its root causes is sparse in Europe (Grothmann and Reusswig, 2006).

In England, the greater community responsibility for flood risk management emphasised in recent strategies (e.g. DEFRA, 2011*b*) has parallels in other areas of government policy, including the present Conservative-Liberal Democrat government's 'Big Society' initiative, which aims to encourage greater involvement and volunteering within communities, which in turn are given more powers (The Cabinet Office, 2010*a*). Indeed, the tendency of upland communities to solve issues on their own has been described as "...a tangible example of the Big Society in action" (DEFRA, 2011*a*: 5). The

U.K. Government also aims to encourage greater community resilience more generally in the face of a broad range of hazards facing the U.K., including natural hazards, health threats, human hazards and terrorism (e.g. the National Risk Register, The Cabinet Office, 2010*b*).

The definition of ‘policy’ which this thesis uses reflects the dictionary definition of the term: that is, “...a course of action adopted or proposed by an organisation or person” (Stevenson et al., 2002: 533). A review of flash flooding by Cave et al. (2009) described “...the national policy context” (Cave et al., 2009: 1), which included the Government’s flood strategy document ‘Making space for water’ and its implications (in England), and the Pitt Review into the 2007 floods and its recommendations, and subsequent legislation. Therefore, within this thesis, the term ‘policy’ is used to refer to government actions and strategies, and their aims and implications, and also the wider scale responses made by institutions (particularly the Environment Agency) to the flood hazard. Where the word 'national' is used in this thesis, this refers to policies, strategies, institutions and responsibilities pertaining/applying to England.

1.4 Implications for research, and thesis objectives

Upland flash floods are an unpredictable and dangerous hazard, posing a major threat to human life (Gruntfest and Handmer, 2001) among exposed communities. The management of flash floods, while a different type of hazard to lowland floods (e.g. Bronstert et al., 2002), needs to be considered in the context of the shift from flood defence to flood risk management as the dominant flood policy approach in England, as a result of an increase in flood risks (Section 1.3). This approach emphasises a more locally based management of risks, with emphasis on the use of local knowledge and increased awareness and preparedness among those at risk, alongside the favouring of individual- and household-level responses (Section 1.3). However, responses to flooding by individuals have been observed to be low (e.g. Thurston et al., 2008, Norwich Union, 2008). This raises large uncertainties as to the nature of the public knowledge of, and response to, rare, extreme flood events such as flash floods, despite the current period of frequent flooding (Section 1.1) and the predicted increase in flash flood events in future (Alcamo et al., 2007). Cave et al. (2009) noted that primary, qualitative research is needed to improve the understanding of flash flood perceptions and vulnerability; and studies of flood risk perceptions could be useful to policy makers (Botzen et al., 2009). Given this situation, research into the factors which influence individual responses and hazard perception to flash floods, as well as the characteristics of knowledge about flash floods and the nature of institutional responses to flash flood events, is particularly important.

Therefore, this thesis uses a case study, interdisciplinary approach to study the responses among local residents and institutions following a major upland flash flood. The case study used is a flash flood event which occurred on the 19th June 2005 in upper Ryedale, North Yorkshire, U.K. The aim of this thesis is to analyse the effectiveness of local- and national-scale responses to upland flash flooding, based upon assessments of the physical flash flood hazard, local adaptations and perceptions, and the flood risk management policy context. This flash flood is introduced in Section 1.5 below and comprised a highly intense, short-lived rainfall event leading to fast runoff to rivers and an extreme flood, affecting small villages and a market town and causing significant damage. An interdisciplinary approach, involving the assessment of climatological and hydrological data and its comparison with locally held knowledge and understanding of flooding, was used to assess flood risks in the upper Ryedale area. The findings from this assessment have been fully integrated with an analysis of the response to the flash flood event by individuals and households as well as responses by relevant institutions. Following this analysis, the implications of the research findings for flash flood management are discussed. The objectives of this thesis are therefore as follows:

Objective 1: To assess the extent to which past flooding in an upland area can be reconstructed using hydrological and proxy records.

Objective 2: To evaluate the 2005 flash flood in the context of the long-term hydrometeorological record.

Objective 3: To analyse public responses to the 2005 flood and the level of flash flood knowledge and perception amongst the residents of upper Ryedale, and the factors which influence them.

Objective 4: To assess the implementation of changes to flood policy, and institutional responses to flash flooding.

1.5 Case study: upper Ryedale flash flood, 19th June 2005

The flash flood event used as a case study for this thesis occurred on the 19th June, 2005 in upper Ryedale, an upland area in the North York Moors, North Yorkshire, U.K. While 'Ryedale' constitutes an administrative district, the term 'upper Ryedale' is used in this thesis to refer to the catchment of the River Rye upstream of the town of Helmsley (SE 615845, Figure 1.2) which is situated at an altitude of c. 50 m above sea level. The catchment area of upper Ryedale is 210 km^2, with a maximum altitude of 454 m at Round Hill (Figure 1.2), which is also the highest point in the North York Moors. The River Rye upstream of Helmsley receives the drainage of the River Seph, downstream of the village of Hawnby (Figure 1.2). Below Helmsley, the River Rye continues for c. 33 km before joining the River Derwent. The River Rye below Helmsley also receives the discharge of several small rivers which drain the southern North York Moors. The River Derwent is a watercourse draining a large part of the southern North York Moors (Figure 1.2). The Derwent flows south and joins a tidal section of the River Ouse, the drainage from this river flowing into the sea at the Humber Estuary (Figure 1.2).

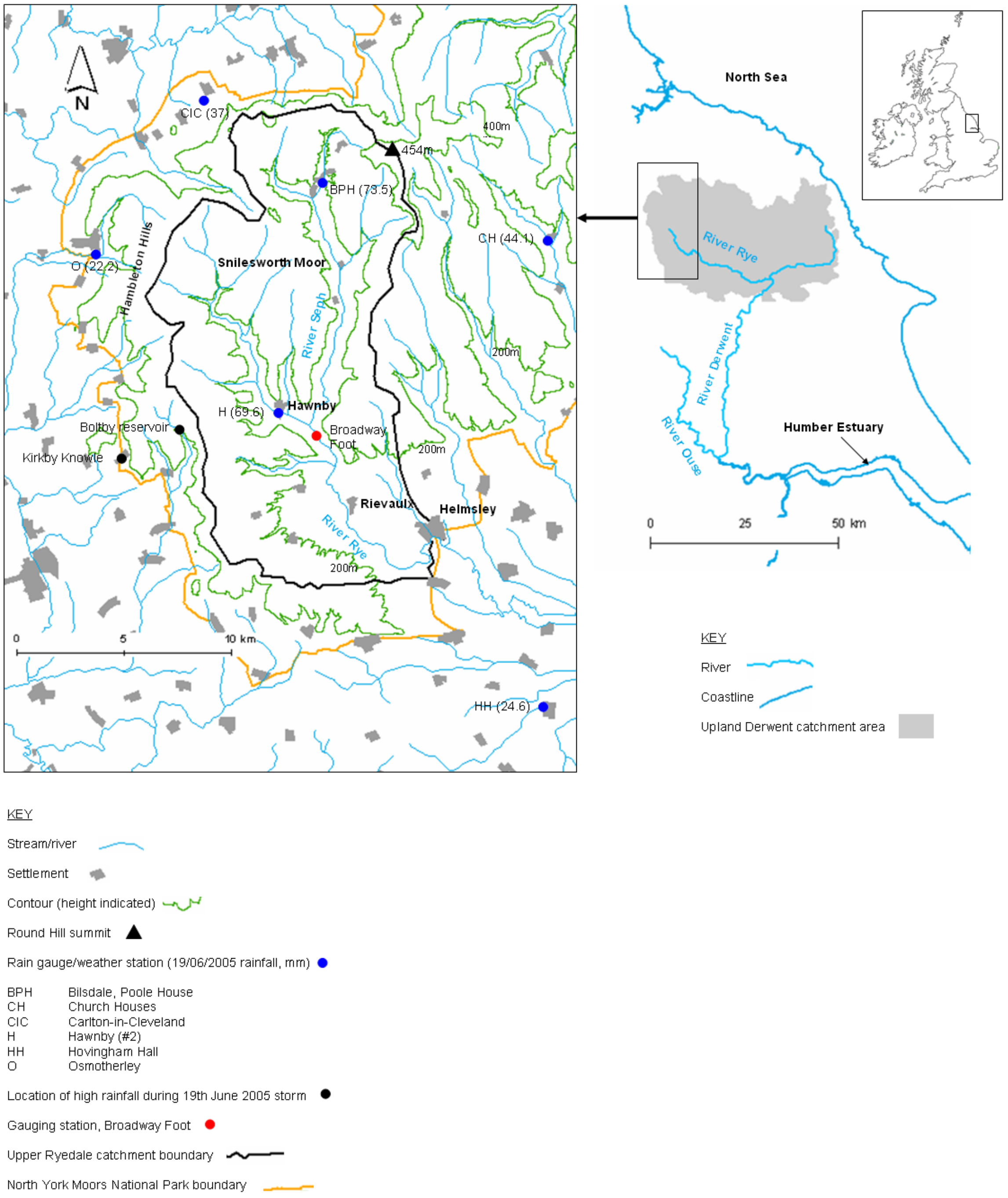


Figure 1.2: Location map of upper Ryedale, showing the case study area and places referred to in the following text. Diagram uses Ordnance Survey Strategi® data: © Crown Copyright/database right 2011. An Ordnance Survey/EDINA supplied service. Rain gauge data recorded by the Met Office and downloaded from the Met Office MIDAS Land Surface Stations database (National Centre for Atmospheric Science, British Atmospheric Data Centre, 2006), except Carlton-in-Cleveland rainfall (source: Cinderey, 2005).

Upper Ryedale is an area of upland moorland and grassland, although some large areas of woodland exist on the steep valley sides. Much of the highest altitude parts of the catchment are peat moorlands, with improved arable pastures situated at lower altitudes and on the valley floor. The upland River Rye drains the south-western part of the North York Moors. Average annual rainfall totals in upper Ryedale are slightly below 900 mm (1961-1990 period) (Bayliss, 1999).

The synoptic conditions and the genesis of the rainstorm which caused the flash flood in upper Ryedale have been described in detail by Wass et al. (2008) and Sibley (2009). The rainstorm fulfilled some 'typical' characteristics of extreme rainfall events in the U.K. (e.g. Hand et al., 2004): it occurred in summer, as a result of convective processes. The 19th of June 2005 saw high temperatures - a weather station at Carlton-in-Cleveland (Figure 1.2), situated to the north of upper Ryedale recorded a maximum temperature of 28.1^{o}C on the 19th of June (Cinderey, 2005), following c. four days of hot and humid weather due to warm, tropical air influencing the U.K. (Wass et al., 2008). The passage of a split cold front, which moved across the U.K. from the south-west, led to the development of strong convection and thunderstorms as a result of "...increasingly cold upper-level air advecting over a warm, moist boundary layer" (Sibley, 2009: 39). The progress of the rainfall is outlined by Wass et al. (2008): a large thunderstorm area covered much of northern England by the early afternoon, with rainfall first developing at 14:30 and above Ryedale at 15:00. The first rainfall at Hawnby was recorded at 15:30. Rainfall data from the tipping-bucket rain gauge at Hawnby, provided by the Environment Agency (Hawnby number two, Figure 1.2) suggests that the bulk of the storm rainfall occurred in the hour before 17:00 (Figure 1.3). Between 16:00 and 17:00, 59.8 mm of precipitation was recorded at Hawnby (86% of the storm total), of which 45.4 mm (65% of the storm total) fell in 30 minutes between 16:30 and 17:00. The peak 15 minute rainfall accumulation was 26.8 mm recorded at 16:45. The storm rainfall total was 69.4 mm, with 69.6 mm of rainfall recorded on the 19th June overall (0.2 mm fell between 19:00 and

19:15). The return period of this storm is estimated as 200 years (for the whole storm) with a longer return period of 330 years for a fall of 64.2 mm in 75 minutes (Wass et al., 2008). While this rainfall was a very rare event locally, across the British Isles, several rainfall events have been observed which are more extreme than that recorded at Hawnby in 2005. As an example, the rainfall event which caused flash flooding at Boscastle, Cornwall in 2004 had a much higher total daily accumulation (184.9 mm), and a greater storm rainfall (181.4 mm in four hours) and hourly accumulation (85.7 mm) in comparison with the upper Ryedale rainfall event (Burt, 2005). Similarly, the 69.6 mm daily rainfall total is relatively moderate in comparison with the highest 24 hour totals on record in the British Isles (Burt, 2005) and the highest short-duration rainfalls recorded (Burt, 2000).

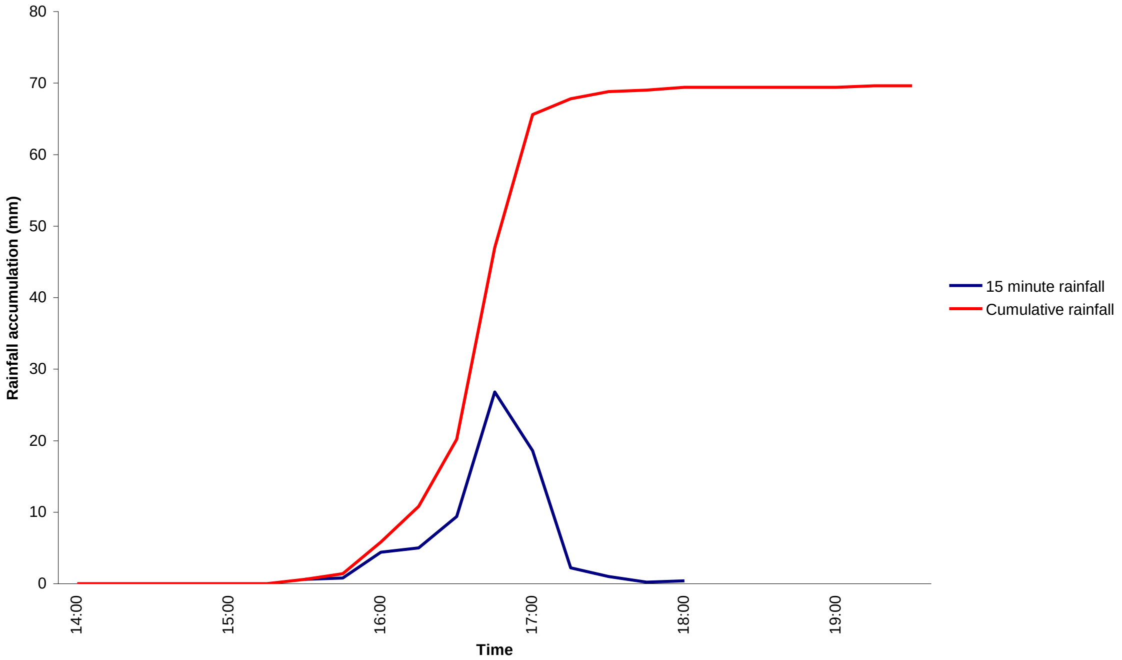


Figure 1.3: Rainfall recorded at Hawnby (number two) rain gauge on the 19th June 2005, showing 15 minute rainfall accumulations (blue line) and cumulative storm rainfall (red line). Rainfall data provided by the Environment Agency.

The daily total rainfall recorded at Hawnby (69.6 mm) was slightly exceeded at a rain gauge eleven kilometres to the north of Hawnby, where 73.5 mm fell at Bilsdale, Poole House (Table 1.2, Figure 1.2). However, it is probable that the sparse network of rain gauges failed to capture the highest rainfall accumulations and intensities (Wass et al., 2008), a common characteristic with particularly localised rainfall (Archer, 1992). This is supported by radar estimates that suggest maximum accumulations in excess of the Hawnby rainfall total, with the highest accumulations occurring in the Kirkby Knowle area (Table 1.2, Figure 1.2). Flood reconstructions at Boltby Reservoir (Figure 1.2) suggest that total rainfall may have been over 200 mm (Walker, 2008; Table 1.2) although this is impossible to verify and well in excess of other estimates. The Hambleton Hills to the west of upper Ryedale (Figure 1.2) received the most rainfall (Wass et al., 2008). The extreme rainfall situated in the upper Ryedale area was clearly extremely localised, and the greatest rainfalls seem to have been unrecorded by rain gauges (Wass et al., 2008). High rainfall totals were recorded at some rain gauges immediately surrounding the Ryedale catchment, including Church Houses, Carlton-in-Cleveland, Hovingham Hall and Osmotherley (Table 1.2, Figure 1.2).

Location	Total rainfall (mm)	Source
Boltby Reservoir catchment	200+	Rainfall-runoff estimate based on flood reconstruction (Walker, 2008)
Kirkby Knowle	127.5	Radar estimate Wass et al. (2008)
Osmotherley-Hawnby area	c. 90	Radar estimate Sibley (2009)
Bilsdale, Poole House	73.5	Rain gauge
Hawnby, Number 2	69.6	Rain gauge
Church Houses	44.1	Rain gauge
Carlton-in-Cleveland	37	Rain gauge Cinderey (2005)
Hovingham Hall	24.6	Rain gauge
Osmotherley	22.2	Rain gauge

Table 1.2: Storm/daily rainfall totals estimated and recorded on the 19th June 2005. Unless otherwise specified, rain gauge data recorded by the Met Office and downloaded from the Met Office MIDAS Land Surface Stations database (National Centre for Atmospheric Science, British Atmospheric Data Centre, 2006).

The rainfall caused significant erosion to several parts of the catchment. On hillslopes, 105 shallow landslides occurred, not including two very large peat slides (the largest covering 3.5 ha) in the Snilesworth Moor area (Galiatsatos et al., 2007; Wass et al., 2008; Figure 1.2) and spectacular downcutting and river bank erosion of streams and gullies also occurred (Figure 1.4). Major blockages of woody debris were also found on the River Rye upstream of Hawnby and were cleared with help from the Environment Agency (source: interview).

Figure 1.4: Major erosion and downcutting in a stream. Photograph provided by Jeff Warburton.

The speed of runoff to the River Rye and its tributaries was extremely fast, with a very short lag time between rainfall event and river level rise as the catchment reacted to the extreme rainfall event in an very different way than it does to normal rainfall (Wass et al., 2008); a characteristic of extreme floods also noted by Archer et al. (2007). The stage of the River Rye rose dramatically, with the river rising three metres in one hour at the Environment Agency's gauging station at Broadway Foot (Figure 1.2) (Wass et al., 2008). Given that no official flood warnings were provided prior to the flood by the Environment Agency for upper Ryedale (they were not available), residents had to react to the event as it was happening (sources: interview data).

The flood caused major physical impacts to communities in upper Ryedale, including severe damage to infrastructure and buildings and the deposition of large amounts of sediment and debris (Figure 1.5). Three road bridges were destroyed or rendered impassable during the flood, causing major difficulties with access to remote settlements of upper Ryedale for emergency services and local authorities. The cost of repairing these bridges alone was £2.9 m (Wass et al., 2008). In Helmsley, Rievaulx and Hawnby, the three largest settlements in upper Ryedale, £1.1 m of damage occurred to 32 affected properties (Wass et al., 2008). Some people situated in the more remote areas of upper Ryedale had to be rescued by helicopter, with others having to rescue members of their families from floodwaters themselves (sources: interviews). No loss of human life occurred, however this was regarded as extremely fortunate, as a large motorcycle rally had taken place on the floodplain of the River Rye outside Helmsley and a large number of the participants had left the site before the flood occurred (Wass et al., 2008; interviews). Private building repairs meant that several residents were displaced for months (source: interviews). Further communications with affected local residents as part of this research project revealed a number of additional secondary or indirect effects of flooding, including a depressed local economy, insurance problems, and health impacts including stress and illness.

Figure 1.5: Damage caused by the 2005 flash flood event in upper Ryedale, photographs taken at Helmsley (top) and Hawnby (bottom), showing damage to infrastructure and property in addition to the deposition of large amounts of fine sediment and debris. Photographs provided by Jeff Warburton.

A spokeswoman for the Environment Agency reflected on the rarity of the flood, saying that the flood event "...did come out of the blue" and described the North York Moors as "...not an area that has a history of flooding or an area where we expect it to happen again" (quoted in Knight, 2005). However, a review of the flood event pointed out that such extreme upland runoff events following heavy rainfall do occur from time to time in the U.K. (Wass et al., 2008). Examples of other recent upland flash flood events in the uplands of northern England include the flooding in Alston and Garrigill, Cumbria in 2007 (Cumberland and Westmorland Herald, 2007; Figure 1.1). Archer (1992) outlined a number of flash flood events which have occurred historically in north-east England, and listed eight recorded daily rainfalls above 100 mm falling between 1898 and 1975; therefore, the daily rainfall recorded at upper Ryedale appears rare, but not regionally unusual over a longer timescale.

1.6 Chapter summary, and thesis structure

The threat posed by flash flood events to upland communities within the U.K. is significant and unpredictable. Given the context of recent policies, which have favoured the management of flood risks, there is a greater onus upon local- and individual-level responses to flood events, with greater responsibilities for such management being transferred from the government to local levels. However, awareness of flood risks and responses to flooding tend to be low among local residents, and the nature of the flash flood hazard also means that large uncertainties exist as to the way in which residents perceive, and respond to, flash floods in particular. Therefore this thesis assesses the factors influencing responses to upland flash floods at the local level by using a case study approach of a major flash flood which occurred in upper Ryedale, North Yorkshire in the summer of 2005.

The second chapter to this thesis comprises a literature review which provides a detailed description of important branches of literature which are relevant, and provide background, to the objectives of this thesis. The literature review assesses the main physical drivers of flash flood risk in the U.K.; additionally, important research into hazard response, preparedness and hazard perception is included, as this is a central area of research in this thesis. The institutional responsibilities for managing flood risks in England, and recent policy changes are also outlined. The remainder of the thesis comprises the following chapters:

- Chapter 3, firstly a review of two central concepts relevant to this thesis: interdisciplinarity and the natural hazards approach. The remainder of Chapter 3 describes the research methodology used and forms of quantitative and qualitative data collected.

- Chapters 4, 5 and 6 contain a presentation and analysis of the data collected, in order to assess the thesis objectives identified in this chapter (Section 1.4). Chapter 4 presents an analysis of long-term rainfall records, and local perceptions of rainfall and climate changes. The other two analysis chapters outline responses to flash flooding, and factors influencing them, by residents (Chapter 5) and by institutions (Chapter 6). Further details of the content of these chapters, and the integration of data into the analysis, is contained in Section 3.6.

- Chapter 7 provides a discussion of the findings of the thesis, identifies key contributions of the thesis to the understanding of responses to upland flash floods, and provides some recommendations for responding to flash floods.

- Chapter 8, the conclusion, is a brief summary of key findings relative to the initial thesis objectives, as well as thesis contributions and recommendations.

Chapter 2

Literature review

The introduction (Chapter 1) described a number of relevant key themes, including a summary of the nature of flooding in the United Kingdom as well as a description of the upland flash flood hazard. It also reviewed literature describing important introductory concepts, including the flood risk management approach. This literature review aims to summarise information relevant to the thesis objectives (Section 1.4). This chapter includes an explanation of the nature of flood risk (Section 2.1), and an outline of factors influencing physical flash flood risks, including changes to heavy rainfall (Section 2.2) and land management and river maintenance (Section 2.3). The next section summarises institutional responsibilities for dealing with flooding in England, and recent changes to flood policies that are relevant to flash flood research, including natural flood management, the lessons learned from the 2007 summer flood events in England and Wales and also changes to emergency response and planning (Section 2.4). Finally, as a study of the responses of local residents to flash flooding forms an important objective of this thesis, a description of factors influencing hazard responses, and flood preparedness (Section 2.5) and hazard perceptions (Section 2.6) are included.

2.1 Key definitions, and the nature of flood risk

A hazard is defined as an event with the potential to cause harm to humans (Few, 2006), with the overall level of risk in an area defined as the probability of a (natural) hazard occurring and the potential for (human) losses (Few, 2006; Smith and Petley, 2009). The risk of flooding occurs as a result of the interactions between natural events and human society (e.g. Kates, 1971; Burton et al., 1993; Parker, 2000; Smith and Petley, 2009). While communities and individuals usually derive resources from the natural environment under 'normal' conditions, extreme conditions cause disasters, which require a response from the human society (Burton et al., 1993; Smith and Petley, 2009). Additionally, Cutter (1996) proposed that the vulnerability of a particular location is a combination of social vulnerability ("...socioeconomic indicators, cognition of risk, individual/societal ability to respond") and physical risk (dependent upon "...site and situation, proximity") (Cutter, 1996: 537).

Physical flood risk at a location comprises the physical hydrological system, the nature of the river basin and river channel and its climatic inputs (Newson, 1994), but human modifications to a catchment area including changes to land use, and further socio-economic factors, influence the flood risk (Chang and Franczyk, 2008; Figure 2.1).

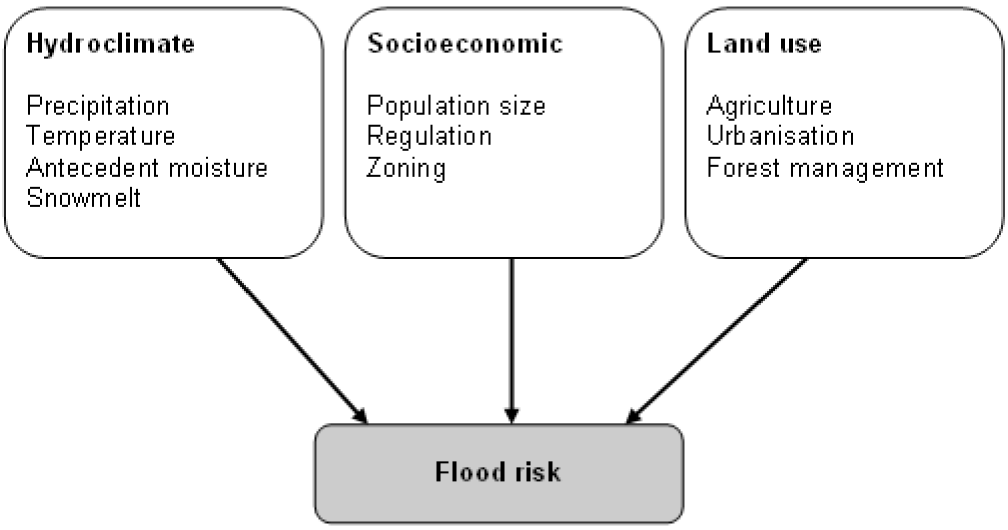


Figure 2.1: Factors influencing flood risks. Diagram redrawn from Chang and Franzyk, 2008, page 1550.

An important physical driver of flash flood risks is the occurrence of heavy, intense rainfall events (Section 1.2). An analysis of such events in upper Ryedale constituted an important part of the study for this thesis, and recent trends in heavy rainfall across the

U.K. are described below (Section 2.2). Further physical drivers of flash flood risks are changes to upland land use and river maintenance. Although no physical data on land use changes was collected during fieldwork for this thesis, opinions and viewpoints on factors affecting local flood risks were studied, and therefore a summary of these factors is provided (Section 2.3).

2.2 Physical flash flood risks: climate change, heavy rainfall and river flows

Extreme summer precipitation events are the main physical cause of flash floods (Section 1.2). Given the possibilities of flooding as a result of extreme rainfall, research in the U.K. has attempted to assess the meteorological causes and timing of extreme rainfall events. Collier et al. (2002) and Hand et al. (2004) have conducted an analysis of 50 extreme rainfall events (based upon the estimated maximum falls possible for durations less than one hour, and the 100 year return period for all other durations). These studies found that 30 out of the 50 events were convective in origin, and that several of the 15 events assessed as being caused by frontal rainfall had a convective element. Importantly, a large majority of the extreme events were found to occur in the summer months (June, July and August), with a very low number of events found in late winter and early spring (February, March and April) (Collier et al., 2002; Hand et al., 2004). Furthermore, Burt (2005) summarised the twelve recorded events in the U.K. where over 200 mm of rain fell in one day: seven of the twelve events occurred in summer (with three additional events in autumn and two in winter). A historical analysis of extreme rainfalls in the British Isles (1866-1968), derived from the archives of British Rainfall, suggests again that the frequency of extreme events peaks in the summer months, with a particularly low number of events recorded in the first five months of the year (Rodda et al., 2009).

A large amount of research has been undertaken into changes to heavy rainfall in the U.K. Although several rain gauge records are short (with the majority going back no further than the 1960s (Lane, 2008)), some trends in rainfall have been found across a number of studies since the 1960s, suggesting increases in winter rainfall, and greater intensities of extreme rainfall events in general (Wilby et al., 2007). With regard to seasonal trends in rainfall across the U.K., Osborn et al. (2000) found an increased contribution of heavy rainfall events to winter rainfall, with a reversal of this trend in summer across the U.K. from 1961-1995. A later study by Osborn and Hulme (2002) also suggested that the frequency of heavy rainfall events in winter was increasing alongside an increase in heavy rainfall contribution to winter rainfall totals. The reverse was found in summer (Osborn and Hulme, 2002). More recent analyses by Jenkins et al. (2008) and Maraun et al. (2008) corroborate these seasonal trends, although there is a suggestion that, from 2001 onwards, heavy summer rainfalls have reversed the longer-term declining trend (Maraun et al., 2008). The spatial distribution of heavy rainfall events across the U.K. is also thought to be changing, as Fowler and Kilsby (2003) suggested that prolonged heavy rainfall events (over a number of days) were increasing (in terms of annual maxima) in northern and western parts of the U.K., based upon observations from 1961-2000. Across the U.K., upland rainfall stations have observed a greater increase in winter rainfall from 1961-2000 than lowland stations (Burt and Holden, 2010); more frequent heavy rainfall in winter has also been found in upland areas (compared with lowland/coastal areas) (Burt and Ferranti, 2012) and the intensity of winter heavy rainfall was found to increase to a larger degree at higher altitudes in Cumbria during the late 20th century (Malby et al., 2007).

With regards to flooding and high river flows, research by Robson et al. (1998) found no long-term trends in flooding in the U.K., and no proof of the impacts of climate change upon river regimes. The tendency for 'flood rich' and 'flood poor' periods (numbers of years which observe a high, or low number of floods respectively) to be experienced in the U.K. was noted by Robson et al. (1998), a theory developed further by Lane (2008). Major flooding in England and Wales in 2007 (Marsh and Hannaford, 2007) has been described as "...a very singular episode", inconsistent with expectations of climate change (Marsh and Hannaford, 2007: 4); Lane (2008) also assessed hypotheses based upon the unusual nature of the floods.

Modelling suggests that, due to a more intense hydrological cycle, heavy rainfall will become more frequent in a warmer climate (Frei et al., 1998). Predictions of future extreme rainfall following climate change across the U.K. have found that extreme rainfall in winter will become more intense, and heavy rainfall will make a greater contribution to summer rainfall (comparison of the 1960-1990 and 2070-2010 periods, Kendon and Clark, 2008). The U.K. Climate Projections report in 2009 suggested an increase in winter precipitation in the future across much of the U.K. by 2080, with a decline in summer precipitation totals. Furthermore, the wettest day in winter will increase in intensity (Murphy et al., 2009). Fowler and Wilby (2010) stated that "The outlook for changes in summer flash flood risk is highly uncertain" (Fowler and Wilby, 2010: 1), as a result of the difficulty in modelling convective storms.

2.3 Land use changes, river maintenance and flooding

Land use changes in rural areas which may influence flood risk include changes in agricultural practices, drainage and afforestation (Wheater and Evans, 2009). Since World War II, the use of agricultural land in the U.K. has intensified, leading to a general increase in runoff (O'Connell et al., 2005, 2007). Changes in upland land management may have influenced flooding in catchments in northern England (Lane, 2003; Orr and Carling, 2006). Importantly, the impacts of land use change represent a stronger influence at smaller spatial scales, while climate changes and variations influence larger geographical areas (Blöschl et al., 2007, Figure 2.2).

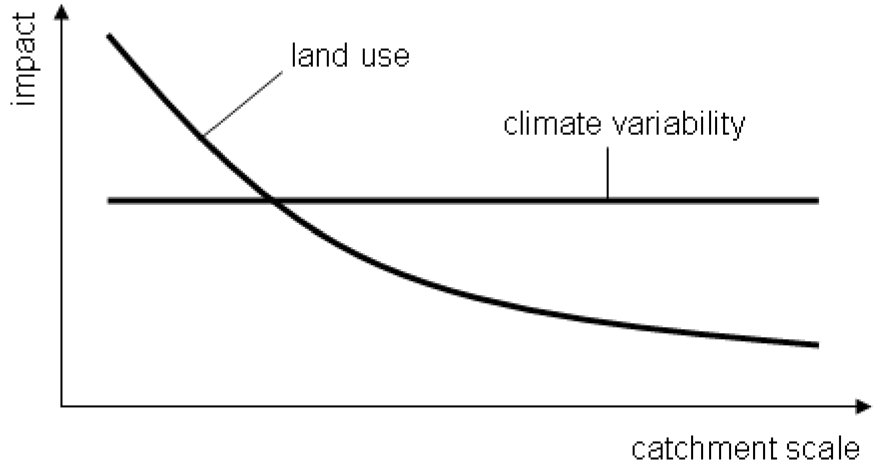


Figure 2.2: "Hypothesized impact of land use change and climate variability on hydrological response as a function of scale." Diagram redrawn from Blöschl et al., 2007, page 1242, caption from same page.

In addition to the above changes in land use, the aggradation of sediment in upland river channels has been linked to changes to flooding (Lane et al., 2007; Raven et al., 2009). Modelling has also suggested increases in erosion and upland sediment yields resulting from increased heavy rainfall and deforestation (Coulthard et al., 2000). It is notable that members of the public have often mentioned the poor maintenance of rivers as a cause of flooding: this has been found in submissions to reviews (Environment, Food and Rural Affairs Committee, 2008), in flood surgeries (Environment Agency, 2007*b*), in the press (Bunyan and Britten, 2009) and in other studies and reports (Werritty et al., 2007; Ryedale Flood Research Group, 2008*a*, Cave et al., 2009).

2.4 Institutional responsibilities for dealing with flood risks, and recent policy changes

At the time of the fieldwork for this thesis, institutional responsibilities for managing flood risks in England were carried out by three main bodies (Table 2.1). The Department for the Environment, Food and Rural Affairs (DEFRA) is a government department and has "...national policy responsibility" for flood risk management (quoted and adapted from DEFRA (2008*b*)), and is "...the lead government department for all flood risk in England" (Environment, Food and Rural Affairs Committee, 2008: 9). Recent flood strategy documents include Making space for water (DEFRA, 2005) and Future Water (DEFRA, 2008*a*) as well as "The national flood and coastal erosion risk management strategy for England" presented to Parliament (quoting the subtitle of DEFRA, 2011*b*). The Environment Agency is a "...Non-Departmental Public Body of Defra" (quoted from DEFRA, 2007), and has responsibility for managing flood risks from those watercourses classified as main rivers within England and Wales (DEFRA, 2007). It has important responsibilities related to flood risk management, including flood forecasting, warnings and the maintenance of flood defences (DEFRA, 2007; Table 2.1): the Agency is "...the lead authority on flood risk information in England and Wales" (Environment Agency, 2006*b*: 3). Both DEFRA and the Environment Agency can be described as 'national' institutions, as they have responsibilities within England (Table 2.1). Local authorities are empowered in England and Wales (Land Drainage Act 1991: Part 5, Section 76, Subsection 3) to carry out flood defence work on watercourses that are a) not main rivers and b) are not within the jurisdiction of internal drainage boards (DEFRA, 2008*c*; Table 2.1).

Organisation	Responsibilities
Department for the Environment, Food and Rural Affairs (DEFRA)	"...policy responsibility for flood and coastal erosion risk management"[1] Funds Environment Agency through grant aid[1] "...the lead government department for all flood risk in England"[2]
The Environment Agency established by Environment Act (1995)[3] powers granted by Water Resources Act (1991)[3]	Flood risk management (on main rivers/the sea) within England and Wales, supervision of: Flood defence Flood forecasting Flood warning, increasing flood awareness[3]
Local authorities powers granted by Land Drainage Act (1991)[4]	Flood defence (on watercourses that are not main rivers, or those under the responsibility of internal drainage boards)[4]

Table 2.1: The responsibilities of DEFRA, the Environment Agency and local authorities for dealing with flood risk, at the time of fieldwork for this thesis. Adapted and quoted from information on the DEFRA website ([1] – DEFRA, 2008b; [3] - DEFRA, 2007; [4] – DEFRA, 2008c) and Environment, Food and Rural Affairs Committee (2008), page 9 ([2]).

As described in Section 1.3, flood policies in England and Wales and Europe over the last ten years have arisen from a philosophy of flood risk management, rather than a more traditional viewpoint of flood protection. In England, the "...national policy context" (Cave et al., 2009: 1), including strategies such as Making space for water (2004, first Government response in 2005), Future Water (2008) and the major review following serious flooding in 2007 (Pitt, 2008), strongly reflects the flood risk management viewpoint.

An important policy change, influencing rural flood risks, is the promotion of natural flood management: "...the alteration, restoration or use of landscape features" to decrease flood risk (Pescott and Wentworth, 2011: 1). This is promoted by the Flood and Water Management Act (2010) and the Environment Agency's Catchment Flood Management Plans (Pescott and Wentworth, 2011). Processes such as wetland creation, managed realignment and rural land management schemes are supported within the Making space for water strategy (DEFRA, 2005). The Flood and Water Management Act lists “...maintaining or restoring natural processes” as a possible method of flood risk management (Flood and Water Management Act, 2010: Part 1, Section 3, Subsection 3b). This policy change has important implications for rural areas, which will see an increase in flood risk (Ryedale Flood Research Group, 2008*a*). This is particularly important in the context of the benefit:cost nature of flood risk management investment, which is likely to be much lower in rural areas, in comparison to towns and cities (Johnson et al., 2007) and schemes in urban areas are very strongly favoured by the funding system (Environment, Food and Rural Affairs Committee, 2008). Furthermore, upland river channels are extremely difficult to manage, as they are in a state of constant change: therefore “...living with the river” may be the best approach (Raven et al., 2010: 37), thus mirroring national strategies, e.g. Making space for water (DEFRA, 2005).

The widespread floods which occurred in the U.K. in summer 2007 (Marsh and Hannaford, 2007) were notable for the predominance of surface water flooding: two-thirds of the flooding was caused this way (Pitt, 2008). Urban surface water flooding, caused by heavy rainfall and inadequate drainage systems, affected the city of Hull particularly badly in 2007, causing the flooding of 8,600 homes and 1,300 businesses (Environment Agency, 2007*b*). Following these floods, the critical observation was made that flood management in England is very strongly directed towards river and coastal floods (Environment, Food and Rural Affairs Committee, 2008). Importantly, flood warnings in England are not designed for quick, sudden floods (Pitt, 2008; Twigger-Ross et al., 2009). Crucially, there is no national warning system for surface water/flash/rainfall flooding (Coulthard et al., 2007; Cave et al., 2009; Coulthard and Frostick, 2010) and the management of risks from surface water flooding was described as being in an “...unclear and chaotic state” (Environment, Food and Rural Affairs Committee, 2008: 15). The Pitt Review into the 2007 floods recommended that the Environment Agency "...should be a national overview of all flood risk, including surface water and groundwater flood risk" (Pitt, 2008: Recommendation 2: xii), with local authorities given a lead role in managing local flood risks (Recommendation 14). Additionally, the modelling of surface water flooding should be improved (Pitt, 2008: Recommendation 5). The Flood and Water Management Act (2010), which became law after the fieldwork period of this thesis had finished, clearly acknowledged these recommendations. The Environment Agency was given the responsibility to "...develop, maintain, apply and monitor" a "...national flood and coastal erosion risk management strategy" in England (Flood and Water Management Act, 2010: Part 1, Section 7, Subsection 1); and local authorities in England were given the role of "...lead local flood authority" (Flood and Water Management Act, 2010: Part 1, Section 9, Subsection 1) which has responsibility for developing strategies to deal with surface water and groundwater flooding and flooding from ordinary watercourses (Flood and Water Management Act, 2010: Part 1, Section 9, Subsection 2).

The 2000s decade has also seen new legislation for emergency planning, clearly relevant to flood management and response. The most important legislation passed in this area is the Civil Contingencies Act (2004). The Act established “...a clear set of roles and responsibilities for those involved in emergency preparation and response at the local level” (DEFRA, 2010: 22). Responders to emergencies are divided into two categories: Category One ("...organisations at the core of the response to most emergencies" (DEFRA, 2010: 22)) and Category Two (“..."co-operating bodies"” (DEFRA, 2010: 23)). Category One responders have important responsibilities, including assessing risks, emergency planning, and to “...maintain arrangements to warn, inform and advise the public in the event of an emergency” (DEFRA, 2010: 22). Both Category One and Category Two responders have the responsibility for co-operating, and sharing information with other responders (DEFRA, 2010).

Following the passage of the Civil Contingencies Act (2004), the Environment Agency are a Category One responder, as are local authorities, the police and emergency services, and the health service (Civil Contingencies Act, 2004: Schedule 1, Part 1). Given the responsibility of Category One responders for emergency planning, in areas where flooding presents a risk, it is recommended that specific multi-agency flood plans are developed by responders (DEFRA, 2010). The aim of multi-agency flood plans should be to "...provide a clear and concise, yet adaptable, response tool under which each responding organisation has clearly defined roles and responsibilities" with the 'triggers' for emergency response for different organisations clearly defined. (DEFRA, 2010: 118-9). Additionally, in order to improve responses to flood events, the Pitt Review has recommended that Fire and Rescue authorities should play a "...leading role" in "...a fully funded national capability for flood rescue", with a statutory duty to do so (Pitt, 2008: Recommendation 39: xxv). As of 2011, the Government is going to assess the need for this (DEFRA, 2011*b*).

2.5 Human decision making, hazard response, adaptation and preparedness

The way in which humans make decisions is an important element of responses to hazards. To quote Sims and Baumann (1983), "Human rationality is constrained not only by its innate weakness in processing information, but also by personality, values, attitudes and beliefs" (Sims and Baumann, 1983: 183). This reflects 'bounded rationality', where humans "...use approximate methods to handle most tasks" (Simon, 1990: 6); the results are decisions which are not optimal, but are adequate enough (Simon, 1990). The importance of the concept of bounded rationality to the mitigation of natural hazards is the implication that humans affected by disasters may not make suitable responses to them, and the further implied importance of needing to understand human perceptions in order to assess responses.

Smith and Petley (2009) summarised three main ways in which humans can adjust to hazards: mitigation (financial measures, such as insurance), protection (structural protection) and adaptation (attempts to reduce vulnerability and increase awareness) (Smith and Petley, 2009). A significant contribution to research into the human behavioural response to natural hazards was made in the 1960s and 1970s by Ian Burton, Robert Kates and colleagues (Burton et al., 1968; Kates, 1971; Burton et al., 1993). Burton et al. argued that "...purposeful adjustment" (Burton et al., 1993: e.g. 59) by individuals, groups or communities to hazards occurred in three main ways: firstly, by accepting losses (such as damage and financial costs) which can be offset by insurance. A second adjustment choice is attempting to reduce losses, which predominantly represents an attempt "...to alter the vulnerability of society to the hazard or event by curbing it or by designing human activities to prevent its injurious effects" (Burton et al., 1993: 60) by using such techniques as hazard warnings, hazard defences and modifications to buildings. Finally, those affected by hazards can choose change: either to change the use of land affected by a hazard, or (most drastically) migrate (Burton et al., 1993). Four factors which influence the nature of adjustment made, according to Burton et al., are "...prior experience with the hazard" (page 199), "...the material wealth of the individuals concerned" (page 199), "...personality traits" (page 199) and "...the perceived role of the individual in a social group" (Burton et al., 1993: 200). Burton et al. (1968) argued that the adoption of adjustments to flooding is strongly related to the frequency, and perceived frequency of flood events, as "A large number of adoptions are made by a high proportion of the population where the probability of a hazard occurrence is high, and where the perceived frequency is equated with positive certainty (i.e., it <u>will</u> happen)" (emphasis as in original, Burton et al., 1968: 19). By contrast, where the likelihood of a flood occurring is low, "...the perceived frequency is equated with negative certainty (i.e., it will not happen)" (emphasis as in orginal, Burton et al., 1968: 19). The adoption of adjustments varies considerably when hazard frequency is moderate and perceptions of hazard frequency are mixed (Burton et al., 1968). Similarly, Kates (1971) noted that "...the frequency of adoption of adjustments appears to be a function of the hazard frequency" (Kates, 1971: 447). Furthermore, responses to flooding have been found to drop off with time after a flood (Baumann and Sims, 1978) and time also reduces awareness of flood risks (Raaijmakers et al., 2008). These factors may be associated with the observation that actions are taken by authorities and residents following a flood, but interest reduces later on (Associated Programme on Flood Management, 2007).

Burton and colleagues also described differences in the physical nature of hazards. Events which are more frequent, longer in duration, have a slow speed of onset, affect larger, diffuse areas on a regular basis can be described as 'pervasive' in nature (adapted from information in Burton et al., 1993: 41), and lowland (and/or frequent) flood events can, broadly, be described as such. However, a localised, sudden upland flash flood event may be regarded as an intensive event. The form of the event is related to responses to it, as "Given a knowledge of the extent to which a type of hazard or a single-hazard event is more nearly intensive, it is possible to predict the types of social responses that are most likely to adopted or to prove futile" (Burton et al., 1993: 43).

The concept of disaster preparedness is an important component of disaster response. In relation to flooding, it is defined as “...the capability of coping with a flood throughout the inundation period, and post-recovery capability and strategies” (Raaijmakers et al., 2008: 312). As a simple model, preparedness for flooding arises as a result of hazard awareness, and subsequent worry about it (Raaijmakers et al., 2008). Preparedness has important social and technical dimensions, which relate to actions taken by individuals prior to a flood event and measures put in place by residents to reduce damage before flooding occurs (Raaijmakers et al., 2008). Others have conceptualised preparedness in similar ways: Kreibich et al. (2005) states that preparedness "...consists of preventative, precautionary and preparative measures" (Kreibich et al., 2005: 118). As described in Section 1.3, household-level mitigation measures have the potential to reduce the level of damage suffered during flooding.

2.6 Hazard/risk perception

Risk perception is defined as "...subjective risk assessment" (Mishra and Suar, 2007: 144). Jasanoff (1998) described different models of risk perceptions and associated policy responses: for instance, traditional (realist) views argue that they are inferior to expert assessments of risk, however constructivist models of perceptions would suggest that both expert and local/'lay' perceptions "...may incorporate legitimate social judgements" within different contexts and settings (Jasanoff, 1998: 94). Other authors view expert and lay assessments of risk as "...prone to distortion due to judgemental limitations" (Slovic et al., 1981: 17), and judgements are also limited by past experience (Kates, 1962).

As summarised by Burton et al. (1993), individuals cannot accurately assess extreme events, in terms of their magnitude and frequency; and the nature of perceptions constitutes a key factor as to why people live in areas prone to hazards, and do not respond to them well (Parker and Harding, 1979). While perception is a potential explanatory factor for precautionary measures against floods (Grothmann and Reusswig, 2006), and that study found that "...perceptual factors are better than the socio-economic factors at predicting flood adaptation" (Grothmann and Reusswig, 2006: 117), other research has found that "... risk perceptions have, at best, only a partial explanatory effect on actual preparedness behaviours" (Kirschenbaum, 2005: 118).

An individual's hazard perception arises from interactions of situational and cognitive factors, and the elements which influence them (Tobin and Montz, 1997, Figure 2.3)). A similar summary was made by Whyte (1986), who argued that three sets of factors influenced perceptions: person-related characteristics, situation-related characteristics and characteristics of the risk itself (Table 2.2).

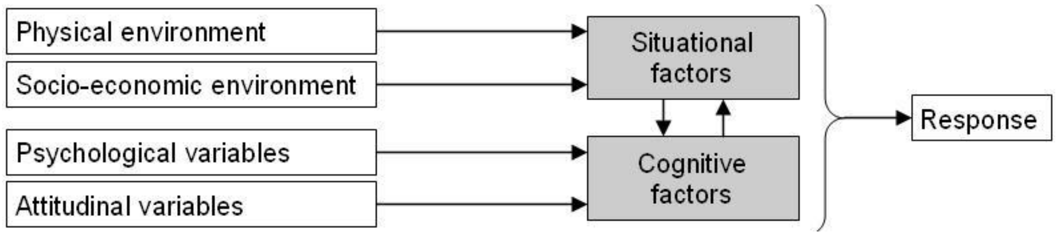


Figure 2.3: Factors influencing the perception of hazards. Diagram reproduced (and slightly adapted) from Tobin and Montz (1997), page 149.

Person-related characteristics	Situation-related characteristics	Risk characteristics
Lower educational levels Female Older Parent Anglophone "Anxious" personality "External" personality	Beyond control of individual Individual at risk involuntarily Short time since previous hazard event Children at risk Inadequate resources available Low credibility in authorities Scientific controversy High media attention No risk analysis	Poses immediate threat Direct consequences to health Mechanisms not understood Probabilities low or uncertain Unfamiliar "new" hazard "Dread" hazard Large number of fatalities per event Fatalities grouped in space and time

Table 2.2: "Factors tending to increase perceived risk compared to scientific estimates". Table and caption reproduced from Whyte (1986), page 254.

A particularly important situational factor influencing perception, as well as protective behaviour, is previous experience with a hazard. This "...generally leads people to see hazards as more frequent and to view themselves as potential future victims" (Weinstein, 1989: 46) and "...leads people to think about the risk more often and with greater clarity" (Weinstein, 1989: 47).

Individuals' views on events which they lack knowledge of are formed by heuristics, which "...reduce the complex tasks of assessing probabilities and predicting values to simpler judgemental operations. In general, these heuristics are quite useful, but sometimes they lead to severe and systematic errors" (Tversky and Kahneman, 1974: 1124). An example of a heuristic is the availability heuristic (Tversky and Kahneman, 1973, 1974), which is where "...people assess the frequency of a class or the probability of an event by the ease with which instances or occurrences can be brought to mind" (Tversky and Kahneman, 1974: 1127). While more frequent events are remembered more easily, availability is influenced by factors unrelated to actual frequency, leading to errors or 'biases' in perception (Tversky and Kahneman, 1973, 1974). Important research into the importance of cognitive factors in risk perceptions was made by Paul Slovic and others in the 1970s and 1980s. Research by Slovic et al. (1981) and Slovic (1987) conceptualised that perception and the demand for regulation of a hazard increases if the risk is feared and, to a lesser extent, if the risk is unknown. The importance of emotions and feelings in influencing perceptions have led to the proposition of the 'affect heuristic' (Finucane et al., 2000; Slovic and Peters, 2006) and the conceptualisation of 'risk as feelings' (Loewenstein et al., 2001; Slovic et al., 2004).

It is important to study risk perceptions, as understandings of environmental issues are formed within a local context (Irwin et al., 1999; Bickerstaff and Walker, 2001; Irwin, 2001). Irwin and colleagues observed that “...issues of environmental risk and public health cannot be separated from the wider settings within which they are constructed and experienced” (Irwin et al., 1999: 1324). For example, climate change is difficult to perceive (Kearney, 1994) and the public are likely to perceive climate through their own experiences, rather than statistically (Hulme et al., 2009). Indeed, research by Whitmarsh (2008) found that flood victims perceived flooding and climate change as “...largely *separate* issues” (Whitmarsh, 2008: 368, emphasis as in original). With regards to flooding, people who have been flooded "...have generally developed a model of the causes of flooding which they can use to predict the likelihood of flooding in the future" (Green et al., 1991: 231). Differences in flood risk perception between experts and the public may result from contrasts between perceptions of aggregated risks (viewed from a wider perspective) and individual risk assessments (Krasovskaia et al., 2001).

2.7 Chapter summary

Alongside the introduction to the flash flood hazard and flood risk management contained within Chapter 1, this chapter has presented a summary of further literature relevant to the scope of this thesis. Chapter 1 described why upland flash flooding constitutes a salient and important research issue: they are different in nature compared to lowland floods (e.g. Bronstert et al., 2002), and flash flood events are highly dangerous, difficult to respond to and difficult to study (Section 1.2). Additionally, flash floods may affect potentially vulnerable upland communities, two major flash flood events have occurred within the 2000s decade (Burt, 2005; Wass et al., 2008), and the flash flood hazard may increase in the future as a result of climate change (Section 1.2). As a result of generally increasing flood risks, evidenced by a high frequency of recent flood events in the U.K. (Section 1.1) and a broader shift towards flood risk management policies which emphasise resilience and increased awareness (Section 1.3), research into flash flood responses and hazard perceptions of the public is extremely important. This wider context informed the thesis aim and objectives described within Section 1.4.

Subequently, this chapter has identified important concepts, theories and frameworks relevant to the thesis and its objectives. The nature of flood risks has been described and factors affecting the physical risk of flash flooding have been outlined. Heavy summer rainfall events are a key physical driver of flash flood risks (Section 1.2) and changes in heavy rainfall within the U.K. have been described within Section 2.2. Therefore, a greater understanding of changing frequencies and magnitudes of heavy rainfall events in upland areas is essential to understanding physical flash flood risks. Within the literature, the value of long upland rainfall records (Burt and Ferranti, 2012) and long-term monitoring records more generally (Robson et al., 1998) has been stated. Therefore, an analysis of a long rainfall record is a key method used within this thesis to assess changes to upland flash flood risks. Additionally, the thesis introduction summarised that the dangers posed by flash flood events result from the characteristics of flash floods (e.g. Gruntfest and Handmer, 2001); however, the study of flash floods is hindered by poor data availability in upland areas (e.g. Macklin and Rumsby, 2007; Section 1.2). Therefore, if river flow data is available in upland catchments which have experienced flash flooding, then there is considerable value in conducting an analysis of elements of this data.

This chapter has also presented a summary of other factors which may influence upland flash flooding. These have included the impacts of land use change, the frequently mentioned issue of river maintenance and broader policy changes including natural flood management. Wider 'lessons learnt', and issues raised, following widespread flooding in England and Wales in 2007 (Marsh and Hannaford, 2007) (Section 2.4) provide an important context which potentially influences institutional responses to upland flash flooding. Other policy changes, including changes to emergency responses and emergency planning are also relevant to institutional behaviour and responses. Due to the difficulties in providing warnings for flash floods (e.g. Alfieri et al., 2011), recognised limitations of the flood warning system in England (Pitt, 2008; Twigger-Ross et al., 2009), the predominant focus upon river and coastal floods in flood risk management (Environment, Food and Rural Affairs Committee, 2008) and changing institutional responsibilities (Section 2.4), assessing institutional responses and policy changes, and their effectiveness at dealing with upland flash floods at the local level, is clearly necessary.

Finally, national policy changes emphasising the importance of resilience, protective measures and awareness of flooding, and a transferral of responsibility for flood responses to the local level have taken place (Section 1.3); however, local responses to flooding have been observed as limited (e.g. Norwich Union, 2008; Section 1.3). Research into residents' responses to, and perceptions of, upland flash flood events are therefore particularly important (Section 1.4). This literature review has summarised key research into hazard responses and preparedness (Section 2.5) as well as perception (Section 2.6).

To summarise, the first two chapters of this thesis have identified important unresolved issues related to upland flash flooding, where further knowledge is required. In order to improve the understanding of the dangerous flash flood hazard, research is required into the following areas:

- Responses to, and perceptions of, upland flash flooding, among affected residents.

- The effectiveness of policy responses to flash flooding, and their implementation at the local level.

- The nature of the changing physical risk of flash flooding in upland areas: particularly changes in heavy rainfall, despite poor data availability from upland areas.

This thesis will increase understanding and knowledge within these research areas. The following chapter contains a review of further literature in two main subjects relevant to the thesis methodology: interdisciplinarity and the natural hazards framework.

Chapter 3

Methodology

This chapter describes, firstly, the key concepts which underpin interdisciplinary, natural hazards research; and secondly the types of data that were collected during this piece of research, as well as the methods used to analyse this data. The aim of this thesis is to analyse the effectiveness of local- and national-scale responses to upland flash flooding, based upon assessments of the physical flash flood hazard, local adaptations and perceptions, and the flood risk management policy context. The four research objectives of the thesis that direct the form of this methodology were stated in Section 1.4.

The first section of this chapter outlines two key elements of this piece of research. The nature of interdisciplinary research, and its relevance in the study of natural hazards, is outlined in Section 3.1, and this section also describes and outlines some participatory studies. Secondly, the natural hazards framework and approach is described in Section 3.2. Following this literature review of background information, key findings, relevant to this research, are outlined and the remainder of the chapter describes the research methodologies used to collect and analyse data in this thesis. Further details of the structure of the remainder of the chapter are contained within the text.

3.1 Interdisciplinary research

In Geography, interdisciplinarity can be conceived as "...the linkage amongst the categories of natural sciences, social sciences and the humanities" (Lau and Pasquini, 2008: 552). By integrating the inputs from different disciplines, interdisciplinary aims to "...promote a more complete understanding" (Lau and Pasquini, 2008: 554).

Broto et al. (2009) has noted a recent increase in interdisciplinary research and work. Thrift and Walling (2000) have identified a particular increase in interdisciplinary collaboration and research involving physical geography. A possible reason for the expansion of interdisciplinary research is the contention that disciplinary research is inadequate to study complex problems (Douglas, 1986; Rhoten and Parker, 2004). Highly complex issues made up of several problems can be conceptualised as 'messes' that cannot be solved by "...solving each of its component problems independently of the others" (Ackoff, 1974: 5): flooding has been thought of in this way, as an "...interdisciplinary object of research" (Donaldson et al., 2010: 1527).

The study of risks to society associated with natural hazards requires an interdisciplinary approach due to the nature of natural processes interacting with human society (e.g. Burton et al., 1993). Integrated studies can "...reveal new and complex patterns and processes not evident when studied by social or natural scientists separately" (Liu et al., 2007: 1513). Slaymaker (1999) recognised that while natural/earth scientists can contribute towards the assessment of hazards, they cannot tackle the important, related studies of risk perception, communication and mitigation: subjects of research that are are best studied by social and applied scientists. Across Europe, it is now recognised that interdisciplinary research (and participatory research) is essential in the flood risk management field (Mostert and Junier, 2009).

With regards to flash flooding, there are uncertainties in areas of physical science and social science, and integrated research approaches into flash flooding are recommended (Montz and Gruntfest, 2002). Flash flood events, due to their distinct character and causes, have been assessed as requiring multi-disciplinary management and warning approaches (Associated Programme on Flood Management, 2007; Drobot and

Parker, 2007). Mitigation against flash floods should incorporate both the physical hazard and human perceptions (Scolobig et al., 2009). In the U.K., the need to integrate technical/scientific and social research (including assessments of 'lay knowledge') to reduce flood risks is now accepted, in contrast to 'traditional' risk management, which takes the view that the public lack information (Brown and Damery, 2002). Accompanying the policy shift in England and Wales towards flood management from the late 1990s (Tunstall et al., 2004; Johnson et al., 2005; Penning-Rowsell et al., 2006), the use of interdisciplinary approaches to study flooding issues has been widespread. Examples include the drivers-based approach of the U.K. Foresight research programme into future flood risks (Evans et al., 2004, 2008). DEFRA has also commissioned the 'Flood Risks To People' project which has assessed the threat posed by flooding to people by assessing both physical risks and vulnerability (Ramsbottom et al., 2003; HR Wallingford, 2006).

Furthermore, the constructivist model of “...risk perception and policy response”, as described by Jasanoff (1998: 93), posits that “Knowledge is most likely to prove authoritative... when it is produced by interaction among multiple stakeholders, each interpreting the available information in the light of its own interests and experiences” (Jasanoff, 1998: 94). A range of participatory methods have been used to study responses and impacts of flooding within the U.K., including studies into resilience, vulnerability and long-term flood impacts in Hull (Whittle et al., 2010, which used diaries, interviews and group discussions), research into hazard perception and awareness (Burningham et al., 2008, using analyses of secondary survey data, focus groups and interviews) and flood impacts upon health (Tapsell and Tunstall, 2008, primarily using focus groups). Comparative research, incorporating a number of case studies from Europe (including primary and secondary data) assessing vulnerability to flooding, risk awareness and preparation has also been carried out (Steinführer et al., 2009). Other participatory approaches involving floods have included the ‘flood histories’ work of McEwen (2007), assessing local knowledge of floods, and a similar project incorporating oral history methods (Insight - University of Gloucestershire, 2010): oral histories and communications “...can be highly profitable” in discovering information about past floods (McEwen, 1987: 138) as can historical flood data more generally (Williams and Archer, 2002). In addition to participatory research, public and stakeholder involvement in flood risk management has advantages: "More personal responsibility" (taken on by the public), "Increased locally specific data", and the "Wider endorsement of decisions" (White et al., 2010: 338). Additionally, in studies of flash flood events themselves, social science methods of data collection have been recommended to improve the understanding of flash floods (Gruntfest, 2009), and personal observations of flash flood events can contribute to post-flash flood surveys, alongside physical data collection and analysis (Gaume and Borga, 2008).

Competency groups of researchers and interested local residents have assessed local flooding issues in North Yorkshire, as part of the 'Flood Controversies' project (Ryedale Flood Research Group, 2008*a*). The Research Group studied flooding issues at Pickering, located 19 km from Helmsley (Figure 3.2), where much of the fieldwork for this thesis took place. Other participatory, interdisciplinary projects have included the Rural Economy and Land Use (RELU) project in the U.K., whose projects use an 'adaptive learning' process involving interviews, focus groups, questionnaires and site visits with stakeholders (Dougill et al., 2006). While local viewpoints and cultural expertise have been disregarded by experts and scientific institutions (Wynne, 1996), expertise in some issues is not just held by scientists and researchers (Ison et al., 2007). The participatory research undertaken into local flooding issues by the Ryedale Flood Research Group (Ryedale Flood Research Group, 2008*a*) has led to the publishing of a number of further papers, which have described the “...knowledge-theoretic” modelling approach used (Odoni and Lane, 2010: e.g. 151) and have explored the nature of knowledge and expertise within the study (Whatmore, 2009; Landström et al., 2011; Lane et al., 2011; Whatmore and Landström, 2011). A key component of the controversy associated with flooding is the “...dissonance between the first-hand experience of flood events and the vernacular knowledge accumulated in affected localities, and the hydrological and hydraulic science that underpins flood-risk estimation and management” (Whatmore, 2009: 594). ‘Local’ or ‘lay’ knowledge, resulting from real-world experience, may challenge scientific knowledge (McKechnie, 1996) and such knowledge may constitute what have been described as ‘contributory’ and ‘interactional’ forms of expertise where individuals possess enough expertise to “...contribute to the knowledge base of the topic in question” and “...allow for interesting interactions between contributory experts”, respectively (Carolan, 2004: 423; after definitions by Collins and Evans, 2002). 'Lay' knowledge may complement institutional knowledge (Irwin et al., 1999). Some local residents may be ‘uncertified’ experts (Lane et al., 2011); in other words, “...experience-based experts...whose expertise has not been recognised in the granting of certificates” (Collins and Evans, 2002: 251). Furthermore, Callon (1999, cited in Pouliot, 2009; Lane et al., 2011) defined three models: the deficit model (which assumes a deficit of public knowledge), the ‘public debate’ model (some roles for public knowledge, but scientific knowledge is still produced by scientists) and the ‘co-production of knowledge’ model. The latter posits that some members of the public have relevant expertise, and have the ability to “...contribute to defining what counts as a problem, determining the make-up of research collectives, and producing and disseminating scientific knowledge and know-how that is drawn on in discussions and debates” (adapted and quoted from Pouliot, 2009: 54). A similar conceptualisation has been made by Klein and colleagues (2011), who described the ideal result of ‘knowledge co-generation’ from participatory research between geographers and other groups; there is a distinct difference between this view, and that of educating the public based upon assumed distributions of expertise (Klein et al., 2011).

The form of natural science and social science research has been described as being very different, as “...researchers in the social and natural sciences ask different kinds of questions, employ different methods, collect different kinds of data, use different analytic tools and produce different kinds of outputs” (Strang, 2009: 5). Interdisciplinary research removes the ‘boundaries’ of methodology and thought and requires an exploratory approach (Bruce et al., 2004), and researchers are required to “...leave, at least temporarily, the familiar territory of their own discipline” (Mostert and Junier, 2009: 4977). The nature of the research subject should inform the decision as to whether to combine quantitative and qualitative research methods (Bryman, 1992). In a research project where both quantitative and qualitative data are collected, sometimes they can be poorly integrated or not integrated at all, as "There is a tendency for most illustrations of integration to involve the use of both quantitative and qualitative research in such a way that each represents a separate block of data collection... Rarely are the two interwoven so that they feed off each other in the sense of stimulating new issues for data collection" (Bryman, 1992: 66). However, when multiple methods of data collection are used, such ‘triangulation’ aims to “...pinpoint the values of a phenomenon more accurately” (Brewer and Hunter, 1989: 17) and “...enhance the validity of research findings” (Mathison, 1988: 13). The combination of methods also compensates for the limitations and flaws of single methods (Brewer and Hunter, 1989). The results of the integration of quantitative and qualitative data may even be unplanned (Bryman, 1992).

3.2 The natural hazards framework

A hazard is defined as an event with the potential to cause harm to humans (Few, 2006). The way in which natural hazards have been studied has changed significantly since the mid-20th century (Tobin and Montz, 1997; Parker, 2000; Smith and Petley, 2009). The flood hazard results from "...an interaction between environmental and social processes" (Parker, 2000: 8).

Furthermore, human sensitivity to natural hazards is a combination of physical exposure (the susceptibility of human society to natural hazards) and human vulnerability to hazards ("...social and economic tolerance" for hazard events) (Smith and Petley, 2009: 11). Similarly, in the U.K., the flood risk to people has been conceptualised as a function of the nature of the physical hazard, and measures of human exposure and vulnerability (e.g. Ramsbottom et al., 2003). Therefore, studies of responses to natural hazards require an understanding of both the physical characteristics of events (natural sciences) and characteristics of the human use system (social sciences) that collectively produce natural hazards (Kates, 1971; Burton et al., 1993; Parker, 2000; Smith and Petley, 2009) (Figure 3.1). Such approaches are replacing studies which solely analysed physical processes (e.g. Tobin and Montz, 1997; Parker, 2000). It has been recognised that "...this combination of natural and human processes... must form the basis of our research into natural hazards if we are to comprehend the real and underlying causes of disasters" (Tobin and Montz, 1997: 132) as natural hazards do not result from physical or human factors alone (Tobin and Montz, 1997).

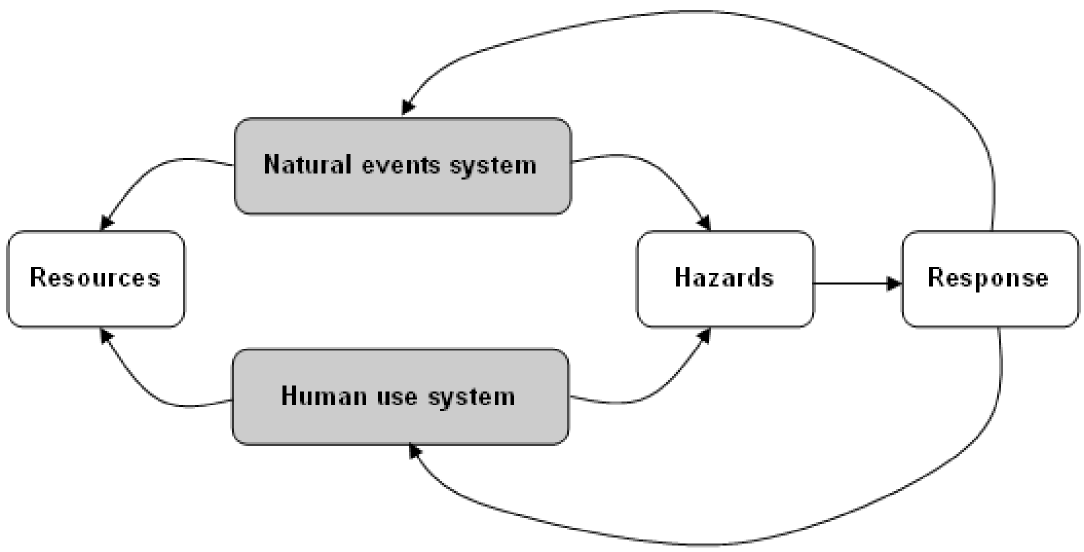


Figure 3.1: Interactions between nature and human society produce both natural resources (useful) and natural hazards, which are potentially harmful and require a response. Diagram redrawn from Burton et al., 1993, page 52, also reproduced in Smith and Petley (2009).

With regards to this thesis, an interdisciplinary, natural science approach was used to study the flash flood hazard, as there was a clear necessity to study individual responses and hazard perception, as well as the need to assess links between these viewpoints and physical data. As a result, the thesis takes a constructivist position with regards to flash flood risk assessment, recognising the importance of responses to flash flooding, and the hazard perception, of local residents, in addition to the analysis of available physical data. The constructivist worldview is that people "...do not just 'experience' the world objectively or directly" (Moses and Knutsen, 2007: 10), but perceive nature differently, based upon individual and social contexts (Moses and Knutsen, 2007). Constructivists would also argue that "Features of society and culture affect the way disasters unfold, how they are perceived and explained, and how their effects are distributed" (Oliver-Smith and Hoffmann, 1999: 73). This thesis assesses both institutional and local/lay viewpoints and perceptions of flooding, as well as responses (and their effectiveness) to an upland flash flood event. In addition, available physical data (including rainfall and discharge data) is compared with local perceptions and knowledge of the local climate.

3.3 Overview of data collection in this thesis

The research for this PhD collected both quantitative and qualitative data (Table 3.1), reflecting the interdisciplinary approach of the thesis, which strongly reflects the natural hazard framework. This thesis presents a study into physical criteria which influence the risks of flash flooding (including heavy rainfall and river flows), but places a study of hazard perceptions, and the factors influencing responses to flooding as a central component of research. This approach results from the nature of the thesis aim and objectives (Section 1.4), and identified research requirements (Section 2.7). Quantitative data collected included physical data (daily rainfall accumulations, and river discharge measurements) as well as questionnaire data, which aimed to assess residents' knowledge and perceptions of flood risks, and their responses to flash flooding. Meanwhile, qualitative data collection involved a series of in-depth, semi-structured interviews with residents who lived in areas directly affected by flash flooding (where property was damaged, following the definition by Penning-Rowsell and Chatterton, 1977), and also institutional stakeholders involved in the flood response (Table 3.1).

	Quantitative analysis	Qualitative analysis
Physical science	Time series analyses: daily rainfall totals, river discharge. Characteristics of high flow events.	Collection of residents' opinions of changes to local climate and flooding.
Social science	Questionnaire, sampling wider population (n = 156).	In-depth interviews, sampling residents of upper Ryedale (n = 19), which include residents directly affected by flooding (n = 12). Also three in-depth interviews with institutional respondents.

Table 3.1: Quantitative and qualitative methods used to collect data in the physical and social science approaches used in this thesis.

The next three sections of the thesis summarise the reasons why some methods of data collection were used, and the ways in which findings from the collected datasets were integrated. Section 3.4 describes the rationale of using two different forms of social science methodologies: interviews and questionnaires. Section 3.5 describes how information about past rainfall and flooding was uncovered from physical data sources, and interviews and questionnaires. Section 3.6 presents a summary of the content of the analysis chapters of the PhD thesis, and also outlines the data sources used within these chapters. Section 3.6 also summarises where the four thesis objectives are assessed within the three analysis chapters. The final two sections describe in detail the data collection and analysis methods which were used in the physical science (Section 3.7) and social science (Section 3.8) areas of research.

3.4 The use of quantitative and qualitative data in hazard response and perception research

Two methods of social science data collection were used within this thesis. The upper Ryedale flash flood directly affected a relatively low number of properties (Wass et al., 2008): therefore in-depth interviews (with 19 individuals) were an appropriate method for fieldwork. The use of a flexible, open-ended interview format enabled a detailed assessment of issues, which included reasons and thought processes behind responses to flooding, that needed to be studied in order to satisfy objectives three and four of the thesis. Additionally, a quantitative postal questionnaire was used to assess potential factors influencing flood response and hazard perception among a larger number of people. In general, qualitative techniques such as in-depth interviews are appropriate where "...complex, discursive replies" to questions are likely (Brannen, 1992: 5), and qualitative approaches are able to study meanings and perceptions (Bullock et al., 1992). Quantitative research "...can provide authoritative survey data and relate diverse factors" (Bullock et al., 1992: 85). The approach to the integration of quantative and qualitative data taken by this thesis is similar to that described by Fielding and Fielding (1986): those aspects of integration which this thesis attempts to use are marked in bold in the following quote:

> "Qualitative work can assist quantitative work in **providing a theoretical framework**, **validating survey data**, **interpreting statistical relationships** and deciphering puzzling responses, selecting survey items to construct indices, and **offering case study illustrations**. In some cases the theoretical structure itself is a product of field experience… **survey results can be validated and statistical relationships interpreted by reference to field data**."
>
> Fielding and Fielding, 1986: 27

3.5 Research into past rainfall patterns and flooding: integration of physical (quantitative) data with social science (quantitative and qualitative) data

In order to assess trends in heavy rainfall, a number of data sources have been used which span both natural and social science approaches (Table 3.2). Firstly, available daily rainfall records were used to form a long-term rainfall series. The most important issue regarding the use of instrumental records is their relatively short-term nature, with few rainfall records existing prior to the 1960s (Lane, 2008); additionally, long-running rainfall records are rare in upland areas (Burt and Ferranti, 2012), necessitating the formation of a composite record of several rain gauges. An analysis of the constructed upper Ryedale rainfall series, complete from 1916 to August 2009, has been published (Hopkins et al., 2010) and the version analysed in this thesis runs to the end of 2009. This 'official' record, derived from the Met Office's monitoring station network, was compared with two sources of data sourced from local residents:

1. 'Private' or 'unofficial' rainfall records kept by some local residents, generally recorded out of a personal interest in the local weather. Two of these datasets were selected for analysis (Section 3.7.1) and were directly compared with 'official' rainfall records (Table 3.2).

2. Perceptions of changes in local rainfall revealed in questionnaires and interviews. Questionnaire responses can be summarised descriptively from the sampled population of Helmsley, and were used to create what have been described as 'semi-quantitative' data (Nicholson, 2001) which can be compared, to a certain extent, with the numerical rainfall series. Interviewees were also asked about changes to local heavy rainfall (Table 3.2).

Source of information about rainfall	Method of data collection and analysis
'Official' rain gauge data	Download of data (Source: Met Office MIDAS Land Surface Stations database, National Centre for Atmospheric Science, British Atmospheric Data Centre, 2006). Organisation/formation of data into long time series (94 years). Analysis of trends in annual and seasonal rainfall and heavy rainfall events
'Unofficial' local rainfall records	Collection of local records based on informal/chance contact through questionnaire. Organisation of data, analysis of trends in annual and seasonal rainfall totals and heavy rainfall events, where available.
Local perceptions of rainfall data	• Questionnaire data, including respondents' estimations of how wet previous decades have been, as well as changes to seasonal precipitation and the frequency of different types of precipitation. • Responses to questions during interviews about trends in rainfall/heavy rainfall.

Table 3.2: Methods of data collection and analysis to study changes in rainfall used in this thesis.

In order to study past flood events, an important limitation of data collection is the sparse and relatively short-term nature of gauging station records, particularly in upland areas and locations which are relatively isolated and inaccessible (McEwen, 1987; Macklin and Rumsby, 2007). The vast majority of gauging stations in the U.K. were commissioned after 1950 (Marsh, 1999). Short-term discharge records present difficulties in placing modern flood events in context (McEwen, 1990; Black and Law, 2004; Macdonald et al., 2006).

Therefore, a number of alternative sources of data and research methodologies can be used to study past flooding. Historical information about past floods can expand knowledge of flooding beyond what is known from flow records (Williams and Archer, 2002). McEwen (1987) made a distinction between quantitative and qualitative sources of flood information: the former is useful for statistical data and physical analysis, however qualitative information is able to give several useful, additional details about flood generation and formation, and the character of flood events, suggesting that both types of data have a role in flood risk assessment. McEwen (1987) describes the use of oral histories (with older residents) as a method which "...can be highly profitable" for establishing flood histories, although the method is described as "...the least reliable method or the most instructive" (McEwen, 1987: 138). With regards to flash floods in particular, Gruntfest (2009) stated the importance of post flood surveys and interviews with those affected by flooding in the research of flash floods. Verbal communication can be useful in establishing the relative magnitude of multiple flood events (Sutcliffe, 1987). As a general rule, in order for a flood to be recorded or remembered, a certain river flow threshold will need to be reached (Benito et al., 2004).

Historical research into flooding has also been used to place modern, large floods into a longer-term context (Bayliss and Reed, 2001; Williams and Archer, 2002; McEwen and Werritty, 2007), and has also been used to improve risk assessments and analyses of extreme events (Williams and Archer, 2002). Assessments of changes in the seasonality, and causes, of flood events over long time scales have also been made (McEwen, 2006).

In order to place the 19th June 2005 flash flood in upper Ryedale into a fuller context, an analysis of a river discharge record from a gauging station in upper Ryedale was carried out (Table 3.3). River discharge data analysed in this thesis was provided by the Environment Agency. In addition, to discover more information about flooding in the local area, local residents were asked for information about their memories of flooding (Table 3.3). In interviews, direct questions were asked about the interviewee’s knowledge of past flooding, and the factors influencing local flood risks. In questionnaires, in addition to other questions about flooding, respondents were asked to mark any floods which they had seen or heard of on a timeline, and to make an assessment of trends in local flooding.

This constituted an attempt to form ‘semi-quantitative’ forms of data (Nicholson, 2001) for analysis. Qualitative information from in-depth interviews was useful as it enabled information on the causes, nature and extent of past flood events to be collected, and accounts were also used to confirm dates mentioned in the questionnaire survey. Other information was received from a few individuals who had been contacted during the questionnaire survey, on an ad-hoc basis. Finally, references to floods from other sources were used in order to provide additional evidence for the past occurrences of flooding revealed by local residents.

Source of information about flood records	**Method of data collection and analysis**
‘Official’ river discharge records	Obtaining river discharge data (provided by the Environment Agency). Analysis of the form of high flow events. Comparison with other river discharge records from the region. Assessment of relationship between high flow events and rainfall.
Local memories of flooding	• Questionnaire data - a) respondents identifying past local floods which they have heard of, and/or experienced. b) respondents' perceptions of changes to local flood risk. c) open-ended responses - details about past floods and factors affecting flood risks • Interview data – residents’ discussion of past floods, changes to local flood risk, open-ended responses • Ad-hoc data collection

Table 3.3: Methods of data collection and analysis used to study changes in river discharge extremes in this thesis.

3.6 Organisation of data and structure of analysis

Table 3.4 shows the different methodologies used to collect data in this thesis, and the main sources of data. In-depth interviews were undertaken with 19 residents who lived in areas directly affected by flash flooding: 15 of these residents lived in Helmsley, three lived in Hawnby and one lived in Rievaulx (Figure 3.2). Of all 19 interviewees, twelve were directly affected by flash flooding in 2005. Three further interviews were undertaken with institutional stakeholders who were involved in the response to the flash flood in 2005: two spokesmen from the Environment Agency and a representative from Ryedale District Council. A postal questionnaire was used to collect data based on a sample of the population of Helmsley (Figure 3.2), constituting 156 responses. Physical data analysed in this thesis included daily rainfall data (series length: 1916-2009) and 15 minute interval river discharge data (1978-2009) as well as some other types of rainfall data and discharge data from other monitoring stations. Additional information used in the analysis presented in this thesis includes ‘unofficial’ rainfall records: private rainfall records collected from some residents through contact following the questionnaire survey, and a photograph of an old flood in Helmsley was also passed on following fieldwork.

Therefore, collected data is organised into three chapters which comprise the data analysis section of this thesis (Table 3.4). The structure of these chapters reflects the initial objectives of the thesis as well as the interdisciplinary methodology. The three analysis chapters all contain analyses of both physical data and social science data, and to achieve this all three chapters contain analyses of both quantitative and qualitative types of data. Information about flash flood responses and perceptions was collected and studied using qualitative and quantitative methodologies (Section 3.4), and the nature of comparisons between physical data analysis and some human perceptions and memories revealed through social science research were described within Section 3.5. The balance of data usage within these chapters is dependent upon the research objectives being assessed (Table 3.5). The first and second objectives of the thesis are assessed in Chapters 4 and 5, the third objective is also assessed in Chapter 5, while the fourth thesis objective is assessed in Chapter 6 (Table 3.5). Therefore, the three analysis chapters are composed in the following way:

Chapter 4 primarily uses data from the questionnaire and the physical rainfall series. The physical daily rainfall record is firstly analysed to assess trends in heavy rainfall over a 94 year period from 1916 to 2009. This record is compared with a second long rainfall series from the north-east of England (Durham), and a wider England and Wales Precipitation Series (dataset reference: Alexander and Jones, 2001). Secondly, privately collected rainfall data series, running from the early to mid 1990s to 2009, were analysed and compared with the measured rainfall series, in order to assess the extent to which such 'unofficial' rainfall records can record changes to rainfall patterns. Thirdly, the perceptions of changes to rainfall were compared with the long-term rainfall record. This perception data, derived from the questionnaire, is presented semi-quantitatively, to describe assessments of the wetness of previous decades and changes to the frequency of heavy rainfall. Finally, qualitative data (in the form of representative quotes from interviews) are used to support, and add more detail to, this questionnaire data.

Chapter 5 is an assessment of the responses to flash flooding made by residents, and the factors influencing them. Two main groups of residents were studied: firstly, twelve residents who were directly affected by flooding in 2005 from Helmsley, Rievaulx and Hawnby (Figure 3.2). Interviews with these residents represent the main source of data to assess their flood responses. Secondly, the wider population of the town of Helmsley was studied through the postal questionnaire, which sampled people who were, predominantly, not directly affected by flooding in 2005. However, responses to flooding among this broader population, and changes in awareness and hazard perception, were assessed using an SPSS analysis involving non-parametric tests and descriptive statistics.

Comparisons are made during the chapter between local viewpoints of flood risks and analyses of respective river flow data, with further links made between locally derived views, discharge analyses and the analysis of rainfall data included in Chapter 4. Discharge analysis in this chapter includes an assessment of the properties of high flow events in upper Ryedale, as well as comparisons of high flow events that occurred in the upland catchments of the River Rye and River Seven, and on the lowland River Derwent. River flow records were recorded at the Broadway Foot, Normanby and Malton gauging stations (Figure 3.2). Additionally, the relationship between river discharge events and rainfall was assessed in greater detail, in order to identify potential flood events that may have occurred in upper Ryedale prior to discharge monitoring. Finally, the factors affecting flash flood risks were assessed using a summary of semi-quantitative data from questionnaires (an analysis of open responses which listed factors influencing local flood risks) as well as quotes from interviews.

Chapter 6 forms an analysis of the in-depth interviews with institutional stakeholders involved in the response to flash flooding in 2005, with a focus on those of the Environment Agency. It is an assessment of responses to flash flooding, and their implementation at the local level, and the chapter includes descriptions of the difficulties the institutions have in responding effectively to flash floods, and also includes a comparison of viewpoints between local residents and institutions. The data analysis in this chapter is predominantly qualitative as it uses data from interviews, with the relevant findings of Chapter 5 compared and contrasted with institutional responses. In addition, findings from physical data analyses are included in the chapter where findings from interviews required further analysis.

Method Data source, sample	**Chapter 4** Reconstructing long-term upland rainfall records	**Chapter 5** Assessment of residents' responses to flash flooding and local flood knowledge	**Chapter 6** Institutional responses to flash flooding, and their implementation
Questionnaire analysis Helmsley population (n = 156)	Yes (data used)	Yes (bulk of analysis)	Yes (comparison with findings of Chapter 5)
In-depth interviews			
Directly affected by flash flooding (n = 12)	Yes (quotes used as evidence)	Yes (bulk of analysis)	Yes (comparison with findings of Chapter 5)
Not directly affected by flash flooding (n = 7)	Yes (quotes used as evidence)	Yes (bulk of analysis)	Yes (comparison with findings of Chapter 5)
Institutional stakeholders (n = 3)			Yes (bulk of analysis)
Rainfall records			
Rainfall data time series, upper Ryedale (1916-2009)	Yes	Yes (comparison with findings of Chapter 4, and assessment of discharge-rainfall relationship)	Yes (comparison with findings of Chapter 4)
Rainfall series: Durham, England and Wales (1901-2009), regional series[1] (1931-2009)	Yes		
15 minute interval rainfall data (Hawnby, September 2004-2009)		Yes (analysis of lag times, and assessment of discharge-rainfall relationship)	
Private rainfall data (1990s-2009)	Yes		
River discharge records			
River flow records, River Rye (1978-2009), River Seven (1978-2009), River Derwent (2002-2009)		Yes (comparison with residents' perceptions and views, and assessment of relationship with rainfall data)	Yes (comparison of the properties of high flow events between different catchment areas)

Table 3.4: Overview of the main data sources and methods of analysis used in the analysis chapters of this thesis. [1] – 'Regional series' are 'North West England & Wales and 'North East England'. Questionnaire and interview data were collected during fieldwork for this thesis.

Objective	Assessment in Chapter:
To assess the extent to which past flooding in an upland area can be reconstructed using hydrological and proxy records.	4, 5
To evaluate the 2005 flash flood in the context of the long-term record.	4, 5
To analyse public responses to the 2005 flood and the level of flash flood knowledge and perception amongst the residents of upper Ryedale, and the factors which influence them.	5
To assess the implementation of changes to flood policy, and institutional responses to flash flooding.	6

Table 3.5: Where the thesis objectives are assessed in the three analysis chapters of this thesis.

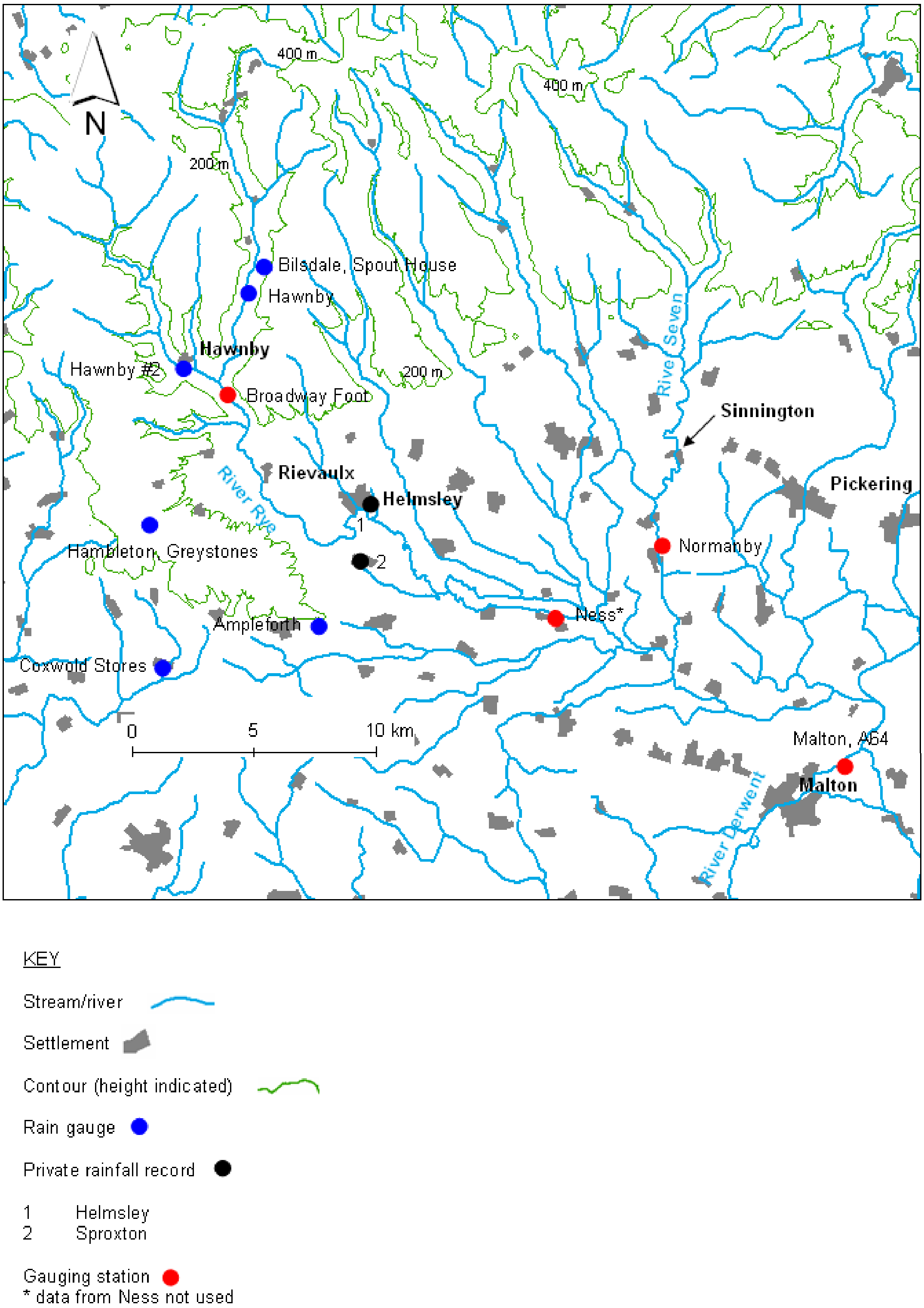


Figure 3.2: Map of the Ryedale area, showing the locations of data sources used in this thesis. Interviews with residents affected by flooding took place in Helmsley, Rievaulx and Hawnby and questionnaire data collection was based entirely in Helmsley. The location of gauging stations (including the Broadway Foot and Ness stations on the River Rye) are noted, and the locations of sources of rainfall data (official and private rainfall records) analysed in this thesis are also shown. Diagram contains Ordnance Survey Strategi® data: © Crown Copyright/database right 2011. An Ordnance Survey/EDINA supplied service.

The remainder of this chapter presents a more detailed description of the specific methods of data collection used in this thesis. Section 3.7 below presents details of the methodologies involved in the physical data collection and analysis. Section 3.8 describes the interview and questionnaire methods of data collection.

3.7 Physical data collection and analysis

3.7.1 Rainfall

In order to assess long-term changes in rainfall characteristics in a particular area, it is advantageous to have a long-running rainfall record based at one site (Burt and Ferranti, 2012). Examples from the U.K. include the very long records maintained by Oxford University (Oxford University School of Geography and the Environment, 2008) and Durham (Burt and Horton, 2007) with daily rainfall records from these stations running back to the 19th century. However, the monitoring network of rain gauges in the U.K. has been described as having a short-term bias, with a large majority of rainfall records only going back to the 1960s (Lane, 2008). At the time of research, only one rain gauge within the upper Ryedale catchment was in operation, a tipping-bucket rain gauge at Hawnby (Table 3.6, Figure 3.2). There was no other 15 minute rainfall data available in the catchment. The other four rain gauges within the upper Ryedale catchment area are also listed in Table 3.6. The lengths of these records of daily rainfall totals are short and discontinuous, and no rainfall data was available from before 1961. Therefore, an assessment of other nearby rain gauges was made in order to extend the data series. A particularly useful gauge at Ampleforth (Table 3.6, Figure 3.2) was found with a daily rainfall record running from 1916 to 1972.

Rain gauge	Location	Altitude (m)	Record start	Record end	Status
		Rain gauges located in upper Ryedale			
Bilsdale, Poole House	NZ 562000	170	01/01/2004	01/07/2009	Closed
Bilsdale, Spout House	**SE 575936**	**143**	**01/04/1977**	**01/12/2003**	**Closed**
Hambleton, Greystones	**SE 528830**	**271**	**01/01/1971**	**01/03/2000**	**Closed**
Hawnby	**SE 569925**	**123**	**01/01/1961**	**31/12/1977**	**Closed**
Hawnby, #2	**SE 542894**	**112**	**11/09/2004**	**-**	**Running**
		Rain gauge records also used in construction of composite rainfall record			
Ampleforth	**SE 598789**	**95**	**01/01/1916**	**01/07/1972**	**Closed**
Coxwold Stores	**SE 533771**	**70**	**01/01/1961**	**-**	**Running**

Table 3.6: Rain gauges recording daily rainfall totals located in upper Ryedale, and rain gauges used in the construction of the composite rainfall record analysed in this thesis (marked in bold). The table is based on information from the British Atmospheric Data Centre (MIDAS dataset, National Centre for Atmospheric Science, British Atmospheric Data Centre, 2006) and does not take into account missing days within the rainfall records. Gauges used to construct the rainfall series are shown in Figure 3.2.

Daily rain gauge data, as defined in Table 3.6 above, is available as part of the Met Office MIDAS Land Surface Stations dataset, available on the British Atmospheric Data Centre website (main website: www.badc.ac.uk, MIDAS database website: http://badc.nerc.ac.uk/view/badc.nerc.ac.uk__ATOM__dataent_ukmo-midas, National Centre for Atmospheric Science, British Atmospheric Data Centre, 2006). Final data downloads to complete the rainfall series to 2009 were made in January 2010. To form a complete rainfall series, the raw (text) data files were converted into a spreadsheet format and processing of the data was carried out to remove unsuitable data: values which had not undergone quality control checking by the Met Office, values collected over more than one day, and values not collected at 9 am.

Where more than one rainfall total was returned for each day, an assessment was made of the quality control code attached to the precipitation amount, with the value furthest through the Met Office's quality control process and/or assessed to be more accurate selected for inclusion in the rainfall series. Finally the data values were 'thrown back' one day. After this, the rainfall data was formed into a continuous series of daily rainfall values by firstly combining the three rainfall records from upper Ryedale. Data from Hawnby was used from January 1961 to March 1977. From April 1977 to November 2003, the record from the Spout House in Bilsdale was utilised, and then the currently operating Hawnby, #2 record was used from September 2004 to 2009 (Figure 3.2). Given that these rain gauges are located close (approximately within five kilometers) to each other, no adjustment of rainfall values from these gauges was made. In order to fill in short gaps within these records, data from two rain gauge records situated close to upper Ryedale were used: gauges at Hambleton, Greystones and Coxwold Stores (Figure 3.2). As these two rain gauges were situated a moderate distance away from the three upland rain gauges described above (and in the case of Hambleton, Greystones, at a higher altitude), it was decided to modify the rainfall values incorporated from these stations. Gaps in series can be filled using monthly, seasonal and annual rainfall totals (Aguilar et al., 2003; Burt, 2009) and where other monitoring stations are available, linear regression has been used as a gap-filling method (Aron and Rachford, 1974). This technique was used to construct the upper Ryedale rainfall series. Correlations were made between a) the combined record of Hawnby, Hawnby #2 and Bilsdale, Spout House and b) the Coxwold Stores and Hambleton, Greystones records, on days where two records recorded rainfall. Correlations were found to be strong between the two rainfall series, with coefficients of 0.85 with Hambleton, Greystones (n = 5,062) and 0.82 with Coxwold Stores (n = 6,966). Therefore regression equations were produced to modify the rainfall values in the Hambleton, Greystones and Coxwold Stores series, and four months of gaps in the upland record were filled with the modified Hambleton, Greystones series, with Coxwold Stores used to fill in nine months and 14 days. This process therefore completed the upland record from 1961 to

2009 inclusive. For the Ampleforth series, six days with no data were filled with 0 mm rainfall as there was no nearby data to fill these gaps. Then the Ampleforth data from 1916-1960 was incorporated, creating a complete, 94 year record of daily rainfall totals for the upper Ryedale area.

As the Ampleforth record is located to the south of the upland area where the other rain gauges are situated (Ampleforth is c. 14 km south of Hawnby), it tends to receive less rainfall than the upland rain gauges. Annual rainfall totals at Ampleforth were, on average, 16.6% lower than those at Hawnby from 1961 to 1972. For this reason, all annual and seasonal rainfall totals are normalised: annual rainfall totals from 1916 to 1960 are expressed as a percentage of the mean annual rainfall at Ampleforth (755.7 mm) and annual totals from 1961 onwards are quoted as a percentage of 889.6 mm.

The remainder of the rainfall analysis, an assessment of trends in heavy and extreme rainfall during the rainfall series, followed similar methodologies to other studies in the U.K. (Osborn et al., 2000; Osborn and Hulme, 2002; Burt and Horton, 2007). Contrasting thresholds of heavy daily rainfall have been used in the literature, however this thesis uses a modified version of a percentile-based threshold defined by Karl and Knight (1998): the daily rainfall total exceeded on 1% of all days in the record (or ‘DR1’). Other threshold values in the literature include the daily rainfall total above which the heaviest x% of rainfall has occurred (Osborn et al., 2000), however in this study the DR1 threshold was selected. The threshold value is slightly different for the two sections of the record, due to the greater rainfall at the upland valley gauges: from 1916-1960 the threshold value used was 20 mm, and from 1961-2009 the DR1 value was 22.8 mm. Although such daily rainfall totals are extremely unlikely to lead to flash flooding, they are acceptable as a means of identifying changes in heavy rainfall over a long period. To assess heavier and extreme rainfalls, maximum daily rainfalls recorded annually and seasonally were also identified, as were the most extreme daily falls across the whole record. To further assess rainfall changes over time, and to compare rainfall changes with other variables, Pearson's correlation coefficient, "...a measure of the linear association between two variables" (Chatfield, 1988: 117) was used. The majority of the rainfall analysis was carried out using Microsoft Excel. Correlation coefficients, r^2 values, and their statistical significance, were assessed using the program Statgraphics Centurion. These programs were also used for the remainder of the physical rainfall analysis.

The rain gauge at Hawnby (#2) (Figure 3.2) also provides rainfall data at 15 minute intervals, available from the 11th September 2004 to the end of 2009 (provided by the Environment Agency). This finer-resolution data enabled a more detailed examination of rainfall events and an additional assessment of some aspects of rainfall-runoff relationships, in particular the ‘lag time’ between rainfall and flow events. The hydrographs of the largest 20 discharge events between 11th September 2004-2009 were assessed alongside the hyetographs of 15 minute duration rainfall data, and the approximate start and finishing points of causative rainfall events were identified from the graph. The start and finish of these events was specified more exactly through a study of the numerical data. Rainfall events were described in terms of peak rainfall rate (highest 15 minute accumulation), duration of rainfall event (the duration of rainfall, excluding intervals with no rainfall), total event and mean rainfall intensity during the event (total rainfall divided by duration of rainfall). These characteristics were used in an assessment of relationships between discharge and rainfall, also mentioned within Section 3.7.2. Finally, the 'lag times’ between rainfall events and discharge events were identified: following the method of Bay (1969), this was defined as the time difference between peak discharge and the point where 50% of rainfall had fallen.

An analysis of a composite rainfall record was thought to be the best means of analysing long-term trends in the frequency, magnitude and annual distribution of heavy rain days in the upper Ryedale area, given the data available. The absence, and limited amount of radar data and 15 minute duration rainfall data for upper Ryedale presented difficulties in the study of variations in the intensity and spatial distribution of heavy rainfall. Rainfall data from rain gauges has known limitations regarding its accuracy (Price, 1999; Davie, 2008), including the under-recording of rainfall during windy conditions and difficulties in the measurement of snow (Sevruk, 1987; Price, 1999), considerations likely to be relevant in upland areas. Additionally, intense rainfall events are frequently poorly recorded by rain gauge networks (Archer, 1992). This happened during the 2005 rainstorm in upper Ryedale: the total rainfall accumulation at Hawnby (69.6 mm) was well below radar-estimated maximum falls (127.5 mm) due to the remoteness of the gauge from the centre of maximum rainfall intensity (Wass et al., 2008). However, well-maintained rain gauge records have proved useful in observing long-term trends in rainfall patterns at other upland locations in northern England, e.g. Moor House (Burt et al., 1998) and Burnhope Reservoir (Holliday et al., 2008).

In addition to the ‘official’ rainfall series described above, during the data collection process of the questionnaire, contact was made with four individuals who had maintained unofficial rainfall records, often as part of an interest in the local weather and climate. Contact was made either voluntarily on the part of residents, or after a further letter was sent to residents who had mentioned that they collected rainfall information. The two longest records within the upper Ryedale catchment area (indicated on Figure 3.2) were maintained at Helmsley by Norman Railton, a record which includes complete data on monthly rainfall totals from 1990 to (summer) 2009, and monthly rainfall totals from 1994 to summer 2009 are also available from a record at Sproxton kept by Alan Agar, located two kilometres south of Helmsley. The latter series also includes some information on heavy rainfalls, including maximum daily rainfall totals recorded. This numerical data could be directly compared with the ‘official’ rainfall series produced above, and an assessment can be made of the extent to which such unofficial observations can represent recent climatic changes.

Finally, in order to compare the changes to rainfall recorded at upper Ryedale with wider patterns of rainfall, two long-term records of daily rainfall totals were also analysed using a similar methodology. Firstly, data from the long-term Durham observatory record was assessed for the period 1901-2009. Durham was chosen due to its location in north-east England (Figure 3.3) and its uninterrupted record of daily rainfall totals. The Durham rainfall series has been the subject of long-term analyses of rainfall and heavy rainfall trends (Burt and Horton, 2007; Burt and Ferranti, 2012). Data from the Durham series was provided by Professor Tim Burt. Secondly, the area-averaged England and Wales Precipitation Series is available from the Met Office Hadley Centre observations datasets website (http://www.metoffice.gov.uk/hadobs/, data download page: http://www.metoffice.gov.uk/hadobs/hadukp/data/download.html; dataset reference: Alexander and Jones, 2001). The England and Wales Precipitation Series was analysed for the periods 1901-2009 (annual and seasonal totals) and 1931-2009 (daily totals). The Met Office series are produced using an averaging method, either based at the England and Wales scale or at smaller or regional scales (Alexander and Jones, 2001). Therefore such a series is less able to capture local heavy rainfall events than individual rain gauge data, and will record lower variations in the record; but the series is useful in comparing general trends in annual and seasonal rainfall, and heavy rainfall, with the upper Ryedale and Durham series. For a further (brief) comparison of seasonal heavy rainfall characteristics, the regional series ‘North West England & Wales’ and ‘North East England’, also available from the Met Office Hadley Centre website at daily intervals between 1931-2009, was analysed.

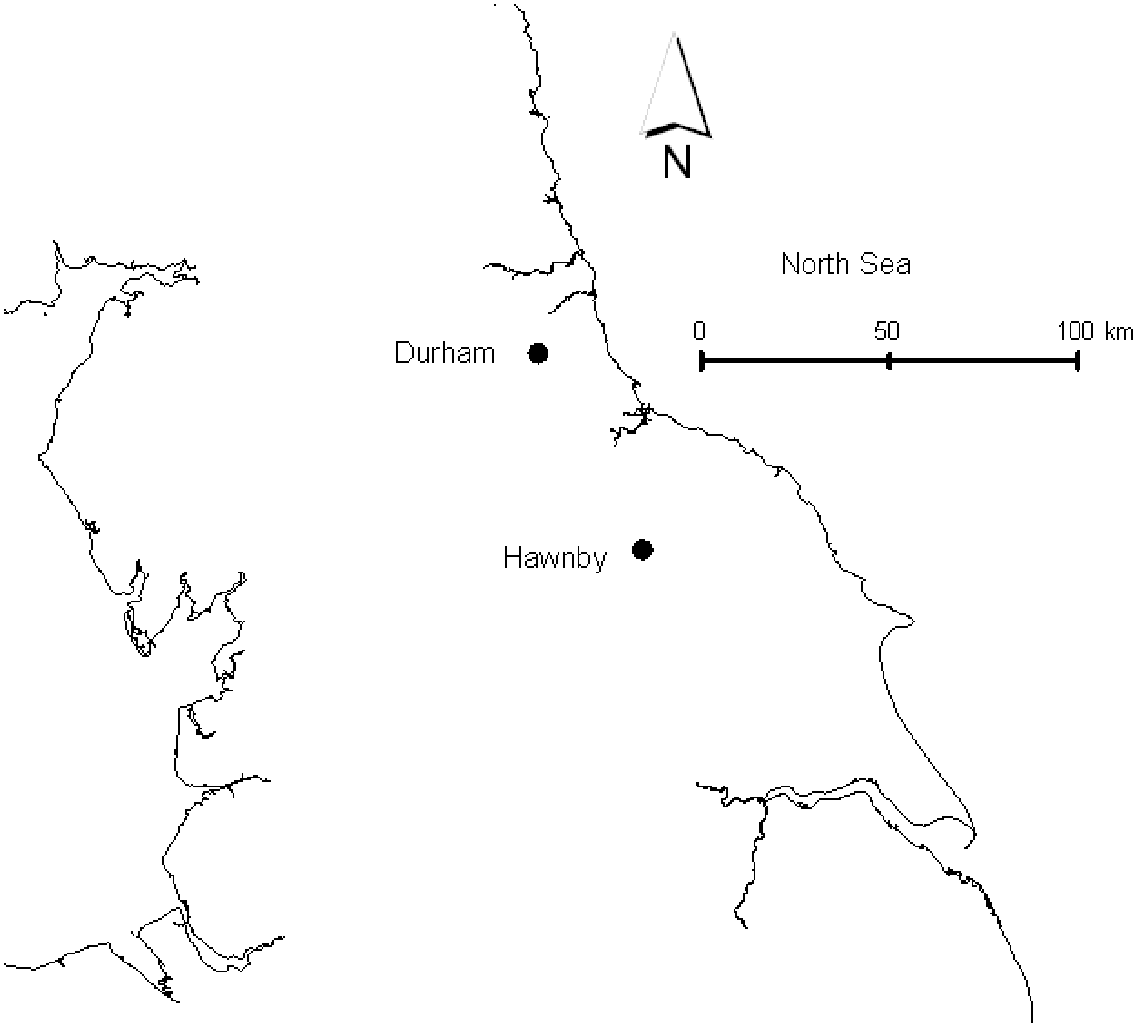


Figure 3.3: The locations of Hawnby and the Durham observatory rainfall record in north-east England. Diagram contains Ordnance Survey Strategi® data: © Crown Copyright/database right 2011. An Ordnance Survey/EDINA supplied service.

3.7.2 River discharge

Data records of river discharges, at a 15 minute resolution, were available from two river gauging stations on the River Rye, one at Broadway Foot (SE 560883, altitude 38 m) located 13 km upstream of Helmsley (Figure 3.2). The second gauging station is situated at

Ness (SE 694792, altitude 26 m), eleven kilometres downstream of Helmsley (Figure 3.2). The station which was further upstream, Broadway Foot, was selected as the basis of analysis. Flow data was supplied by the Environment Agency for Broadway Foot and two other gauging stations at Normanby and Malton (Figure 3.2).

To study the flow regimes of watercourses, Poff et al. (1997) suggested five main components of the flow regime: magnitude, frequency, duration, timing and rate of change (Table 3.7). In this thesis, river discharge data is used in comparison with findings from social science research, in the form of viewpoints derived from institutions and the public. This thesis uses the available river discharge data to assess the runoff characteristics of high flow events. High flows were evaluated based on aspects of the magnitude component (peak discharge) and rate of change (rate of discharge increase, and lag time between rainfall and flow events) (Table 3.7) as well as trends in high flows over the length of the River Rye record, and seasonal characteristics of high flow events. Further comparisons were made between high flows at Broadway Foot and those recorded at Normanby and Malton.

Component of flow regime	Description
Magnitude	"...the amount of water moving past a fixed location per unit time" ([1])
Frequency	"...how often a flow above a given magnitude recurs over some specific time interval" ([1])
Duration	"...the period of time associated with a specific flow condition" ([2])
Timing	"...the regularity with which (flows of a defined magnitude) occur" ([2])
Rate of change	"...how quickly flow changes from one magnitude to another" ([2])

Table 3.7: The five main components of a river's flow regime. Adapted and quoted from Poff et al., 1997: [1] - page 770, [2] - page 771.

Thresholds of high river flows have been defined in a number of ways. Some researchers assessing the impacts of land use changes upon river flows have used thresholds based upon flows being above a certain multiple of the median flow (Archer and Newson, 2002; Archer 2003), and others have used the flow exceeded for a certain proportion of the full record (Karl and Knight, 1998). The discharge analysis for this thesis aims to look at the characteristics of the highest river flows on record, and therefore a simple measure of the highest n of events is used. Table 3.8 below shows how the high flow events from the River Rye, River Seven and River Derwent records were classified and used in different sections of analysis, with the subsets of data analysed in ways that answered questions and issues which arose during interview and questionnaire analysis. Further information about the nature of discharge data analysis is included throughout the thesis in the captions of tables and figures that present the findings of the data analysis. The availability of some concurrent 15 minute rainfall data from the Hawnby rain gauge in upper Ryedale from the 11th September 2004 onwards (data provided by the Environment

Agency) meant that lag times between rainfall intensity peaks and river flow peaks could be assessed. Measurements of the average rate of discharge increase, as well as lag times where 15 minute rainfall data is available, enable the speed at which a river responds to be measured. In particular, the flashiness of rivers: the "...rapidity of short term changes in streamflow" (Baker et al., 2004: 503), is a particularly important component to assess as it is strongly linked to the risk posed to life and property by flood events (Ramsbottom et al., 2003).

River (Gauging station) Number of events Time period Effective threshold (m^3 s^{-1})	Reason for analysis	Characteristics of discharge events assessed
River Rye (Broadway Foot) Largest 50 events 23/08/1977-31/12/2009 47.4	Overall characteristics of high flow events on the River Rye, including trends in river flows and seasonal patterns.	Peak discharge Mean rate of discharge increase
River Rye (Broadway Foot) Largest 20 events 23/08/1977-31/12/2009 65.6	Comparison of characteristics of high flow events on upland River Rye with those of other rivers (River Seven, River Derwent).	Peak discharge Mean rate of discharge increase
River Seven (Sinnington) Largest 20 events 13/07/1977-31/12/2009 105	Comparison with largest 20 events from River Rye record, above	Peak discharge Mean rate of discharge increase
River Derwent (Malton) Largest ten events 08/10/2001-31/12/2009 56.2	Comparison with largest 20 events from River Rye record, above. Only ten events are analysed due to the much shorter record.	Peak discharge Mean rate of discharge increase
River Rye Broadway Foot Largest 20 events 11/09/2004-31/12/2009 33.9	Events during period of 15 minute rainfall data availability in upper Ryedale catchment.	Peak discharge Lag time (peak rainfall intensity to peak discharge)

Table 3.8: The high flow events recorded on the River Rye used for analysis and comparison in this thesis, showing the characteristics of the events to be described. River gauging stations are shown on Figure 3.2. Within the thesis, the periods of discharge records are often referred to as starting at the first complete year (e.g. the River Rye at Broadway Foot, 1978-2009). Discharge data provided by the Environment Agency.

Due to the large volume of discharge data, the complete datasets were stored in SPSS and Microsoft Excel. SPSS is able to display extremely large quantities of data, and therefore this program was used to store the full Broadway Foot series (1978-2009) (Table 3.8). Discharge events were defined by firstly identifying their peak discharge, and subsequently studying the discharge graph in order to assess the start of the event; the point in the time series where flow began increasing by 0.1 m^3 s^{-1} for one 15 minute interval was regarded as the start of the event. The nature of low discharges, and the presence of low (secondary) flow peaks near the start of large flow events were taken into account in assessing the start of the event. Some flow events with multiple peaks were found (particularly long, complex events occur within the Malton record), for which a subjective assessment was made of the most appropriate start point for the discharge event. In a very small number of cases, where data was missing at the peak of a discharge event, the event was not included in analysis. The peak discharge of the 2005 flash flood was not directly measured, due to the gauge failing at Broadway Foot (Wass et al., 2008), therefore the estimated peak discharge of 400 m^3 s^{-1} (at 18:15 on the 19th June) by Wass et al. (2008) was used for this event. Once the characteristics of discharge events were identified, this data was then analysed within Microsoft Excel.

High flow events on the River Rye were compared with those on the River Seven and River Derwent as comparisons were made by interviewees between flooding in upper Ryedale and flooding in Sinnington (on the River Seven) and also downstream flooding (at Malton) (Figure 3.2); furthermore, greater attempts to mitigate against floods have taken place at Sinnington (described within Chapter 6). The Rye and Seven catchments are similar in terms of their area, annual rainfall and mean flows (Table 3.9) and drain upland, moorland catchments. The River Derwent has a different flow regime with a notably much larger mean flow (Table 3.9), as it collects the drainage of all the tributaries from the southern North York Moors national park, including the River Rye (which itself is joined by the River Seven). In order to directly compare the three catchments, discharge measurements are quoted as a multiple of long-term mean flows (Table 3.9), therefore using a similar method to the studies by Archer and Newson (2002) and Archer (2003) which used multiples of the median flow.

Station	Catchment area (km^2)	Altitude (of station, m)	Mean flow ($m^3\ s^{-1}$)
River Rye at Broadway Foot[1]	131.7	37.7	2.31
River Seven at Normanby[2]	121.6	28.5	1.94
River Derwent at Malton (A64 road bridge)	1,360.1[3]	14.6[4]	13.18[5]

Table 3.9: Descriptive statistics for the three gauging stations used for discharge analysis in this thesis. Information based on data from the Centre for Ecology and Hydrology and Environment Agency HiFlows U.K. websites. References: [1] - Centre for Ecology and Hydrology, 2011a, [2] - Centre for Ecology and Hydrology, 2011b, [3] - Environment Agency, 2011a, [4] - Environment Agency, 2011b. Mean flows at gauging stations based upon long-term (1974-2009) mean. [5] - Mean flow estimated at Malton based upon average flows of tributaries (Centre for Ecology and Hydrology, 2011b, c, d, e, f, g, h, i). Mean flows correct as of September 2011. The locations of the three gauging station records analysed are indicated on Figure 3.2.

Finally, an attempt has been made to use the much longer daily rainfall record from upper Ryedale (running from 1916-2009) to identify possible overbank flood events, including those which occurred prior to the period of river discharge monitoring within upper Ryedale (prior to 23rd August 1977). This is based upon an analysis of the relationship between high flows recorded at Broadway Foot and the assessed causative rainfall events. This section of work contains analyses of discharge data and also rainfall data (at daily and 15 minute duration scales). A description of the methodology for this analysis is contained alongside its findings within Chapter 5.

The use of the discharge data has some limitations with respect to the gauging stations which collected the data. Estimated measurements of flood flows can be uncertain, and "...care should be taken in evaluating estimates of the higher peaks" (Shaw et al., 2011: 256); where gauging stations are bypassed during flooding, the measurement of overbank flows is very difficult (Newson, 1994). Sometimes high flows are estimated based upon extrapolations of rating curves (Costa and Jarrett, 2008; Shaw et al., 2011). Observing the data used within this study, several moderate to high flows on the River Seven are estimated, as the gauging station at Normanby drowns at moderate flows (Centre for Ecology and Hydrology, 2011*b*). Furthermore, some sections of data are missing. For the majority of the records such sections are very short and sporadically distributed throughout the record, and as such do not interfere with high flow events. However, at Broadway Foot the 2005 flash flood caused severe damage to the gauging station (Wass et al., 2008), meaning that the station had to be rebuilt (Centre for Ecology and Hydrology, 2011*a*). Therefore, no data was recorded between the 19th June 2005 and the 27th October of the same year, and no data was recorded for c. one year from June 2006, meaning that no events were recorded during this time. However, a large number of high flow events at other parts of the record were recorded.

3.8 Social science data collection and analysis

3.8.1 Interviews

In order to research local respondents' knowledge and response to flash flooding, a series of in-depth, semi-structured interviews were undertaken in 2008 with residents who lived in areas that had been directly affected by flash flooding in 2005. In addition, three further, one-on-one interviews were undertaken with stakeholders (the Environment Agency, Ryedale District Council). Semi-structured interviews are a form of interview where there is a predetermined set of question topics, but there is greater flexibility and freedom in how the informant responds to and addresses these questions: they lie in between unstructured interviews (where the conversation is directed by the informant) and structured interviews (which use a rigid structure of predetermined questions) (Dunn, 2000; Cook and Crang, 2007; Denscombe, 2007). Semi-structured interviews have the advantage of being relatively conversational and informal, and allow for open responses from the interviewee(s) (Longhurst, 2003).

To identify areas of settlements in Ryedale which had been inundated by floodwaters in the 2005 flash flood event, flood extent data from the Environment Agency was assessed using ArcGIS. This data consists of a post-flood survey carried out by the Environment Agency immediately after the flood event (Figure 3.4). The areas of the settlements of Helmsley, Rievaulx and Hawnby (Figure 3.2) which were directly affected by flooding in 2005 could be identified: in total, 40 properties were identified as being potentially directly affected by floodwaters. These properties were sent a letter detailing the research project, and residents were invited to send back a reply slip in a provided stamped, addressed envelope if they were willing to be interviewed. Following the receipt of replies, telephone contact was made with individuals who expressed an interest in being interviewed. From these, 14 interviews took place with 19 people between July and October 2008 (Table 3.10). Directly affected residents in Helmsley were concentrated in the Ryegate, Sawmill Lane and Bridge Farm Close areas of the town, which are situated close to the River Rye (Figure 3.4). At a later date, further letters of interest were circulated to some houses downriver of Helmsley, however interest in interviews was not forthcoming and it was decided to concentrate the research solely on upper Ryedale.

Interview number	Date	Sex	Location
1	1st July 2008	Male Female	Hawnby
2	20th August 2008	**Male** **Female**	**Helmsley**
3	3rd September 2008	Male[1] Female[1]	Helmsley
4	3rd September 2008	**Male**[2]	**Rievaulx**
5	3rd September 2008	**Female** Female	**Helmsley** Helmsley
6	17th September 2008	**Male** **Female**	**Helmsley**
7	17th September 2008	**Male**	**Hawnby**
8	17th September 2008	**Male** **Female**	**Helmsley**
9	18th September 2008	**Female**[2, 3]	**Helmsley**
10	18th September 2008	Female	Helmsley
11	18th September 2008	Male	Helmsley
12	24th September 2008	**Male**	**Helmsley**
13	9th October 2008	Female[4]	Hawnby
14	9th October 2008	**Male**	**Helmsley**

Table 3.10: Details of the interviews with local residents of Helmsley and upper Ryedale, undertaken in summer-autumn 2009. Individuals in bold were directly affected by flooding in 2005.
[1] - the individuals in this interview did not live in the same house, and had replied separately, but were interviewed together.
[2] - at these interviews, other people were present, but did not contribute to the interview.
[3] - interviewee had moved into property three years prior to interview.
[4] - female interviewee from interview 1 was interviewed again in order to ask new questions.

All the interviews took place in residents' homes and all interviews were recorded with the interviewees' prior consent. The settings of the interviews were all agreed beforehand and the home setting provided a comfortable environment for the interview, particularly as many of the interviewees were older and/or lived on their own (the oldest resident interviewed was 90 years old). The average length of an interview was just under 39 minutes long (most interviews lasted between 30 minutes and an hour in length).

Twelve interviewees had been directly affected by flooding in 2005. The data from these twelve interviewees was used to assess responses to flash flooding in 2005, and the factors which affected them. Meanwhile, data from all 19 interviewees was assessed in order to study memories and knowledge about past and local flooding, as well as changes to the local climate and views on the factors affecting local flood risk. Quotes and information from interviews with residents are presented in this thesis in an anonymised way, with no names or details included about respondents beyond their gender.

Each interview attempted to cover a number of topics for discussion. However, as stated above, the interviews were not rigidly structured, and in several interviews some topics were only briefly discussed while others were covered in more detail. Similarly, although there was a broad list of topics to discuss in the interviews, the order of the topics was flexible, and sometimes the interviewees led the direction of the conversation. An interview outline is included in Appendix 1. The freedom offered in responses meant that other topics, not previously considered for research, were discussed. Some interviewees possessed newspaper cuttings or photographs of the local flooding, while others allowed photographs to be taken around their property.

In order to assess institutional views and responses to flash flooding, three further interviews took place with stakeholders who were directly involved with the response to the 2005 flash flood. Two spokespeople from the Environment Agency, who were involved in the Agency's response to the flash flood, were interviewed in early 2010, along with a representative from Ryedale District Council. Following initial contacts with individuals at the Environment Agency (in late 2009), two members of staff, were contacted (internally) at the Agency as they were felt to be suitable to speak to about the 2005 flash flood. These members of staff then contacted the thesis author and interviews were arranged. The representative from Ryedale District Council was recommended to the author by one of the Environment Agency interviewees. Although the findings of interviews with residents of upper Ryedale were not discussed in these interviews, topics raised by residents were discussed. Again, the interviews were semi-structured with considerable freedom for responses from the interviewee, and in many cases the interviewee defined the topic of discussion. A summary of key topics discussed and questions used in these interviews is included in Appendix 1.

During the summer of 2011, after both interviewees were re-contacted, one interviewee from the Environment Agency clarified some of the quotes used from the transcripts of his interviews. In Chapter 6, these clarified statements are shown by bold text. Questions asked by the researcher are shown in italics, in all interviews.

Recommendations and guidelines for the structuring and wording of questions do exist for interviews (e.g. Longhurst, 2003; Valentine, 2005; Cook and Crang, 2007; Denscombe, 2007). Attempts were made to avoid leading questions, and instead open-ended questions were asked, giving respondents scope for detailed answers. Opinions given by interviewees were generally probed with further questioning (e.g. 'Why?').

The analysis of interview transcripts took place within Microsoft Word. The transcripts were scanned and read, and sections of questions and responses relevant to research objectives were identified, copied and collated separately. Therefore, similarities between different responses could be identified, and key factors affecting flood response and flood risk perception were also pinpointed. Other opinions and viewpoints related to interview topics and local flooding were also noted. Although transcript extracts are useful, "It is very unlikely... that an extract from an interview transcript can be presented as proof of a point" as the extracts are used (within reports) out of context, and selecting the extracts to use is a subjective decision (Denscombe, 2007: 199). It can be difficult to generalise the results of qualitative research (Bryman, 1988 (cited in Bryman, 1992); Bryman, 1992) and due to the small sample sizes and non-random nature of interview samples, generalisations about the results of the interviews cannot usually be made (Boyce and Neale, 2006). In this thesis, interview quotes chosen to be included for analysis are clearly defined using a grey box. They include representative viewpoints from those being interviewed, and are made to support either a) majority viewpoints among many interviewees, and/or b) particularly interesting viewpoints from one particular interviewee. Interview quotes are therefore used in this thesis in three main ways:

1. To support the findings of the wider questionnaire survey, which was based on a largely random sample and has a much larger sample size.

2. To support majority viewpoints from the twelve interviewed local residents who were directly affected by flooding, or to summarise institutional viewpoints from the three individuals interviewed.

3. To support, as evidence, particular factors which have influenced resident or institutional responses to flooding.

3.8.2 Questionnaires

The form of the postal questionnaire, and the questions within it, was influenced by responses received in semi-structured interviews which were undertaken with residents living in areas of Helmsley and upper Ryedale that were directly affected by flooding in 2005 (Figure 3.2, Section 3.8.1). A number of ideas about factors influencing responses to flash flooding, perceptions of flood risk and factors affecting it were formulated following initial interviews. A decision was made to attempt to quantify such factors across a wider population (the town of Helmsley). A copy of the questionnaire is shown in Appendix 2 at the end of the thesis, and a list of variables derived from the questionnaire is shown in Appendix 3. The questionnaire was designed to collect information on seven sets of variables. Increased understanding of two particular variable sets (flood perception, and response to the 2005 flood) was an important element of the third thesis objective. Non-parametric tests were used to assess associations between these two variable sets and the other five sets of variables. Flood risk perceptions were also potentially associated with responses to the 2005 flood. The seven variable sets can be named thus:

- Flood risk perception
- Response to 2005 flood
- Demographic characteristics of respondents
- Location of respondent's house
- Experience of flooding in 2005
- Overall flood experience
- Perception of rainfall change

The variables for investigation were selected as several common themes arose from interviews which required further analysis, and secondly, as a review of available literature suggested several factors that may impact upon response to natural hazards. Given the fact that the 2005 flash flood directly affected a relatively small area of Helmsley (Figure 3.4), a large number of individuals who had received the questionnaire would not have been directly affected by flooding. Therefore, responses to flooding assessed by the questionnaire included awareness of flood warning and information services provided by the Environment Agency, including Floodline Warnings Direct, flood maps (referred to as

‘Flood risk maps’ in questionnaires) and the flood warning symbols used in the communication of flood warnings. Floodline Warnings Direct is a free warning service which contacts individuals if flooding that may affect their property is expected: the service also provides a telephone number which can be contacted by residents to discuss flood risks (Environment Agency, 2011*c*). The Floodline warning service was not available in the Helmsley area and those areas surveyed during this project. The Environment Agency’s flood map is available online and indicates areas at risk of flooding (at different statistical likelihoods) and the locations of flood defences and areas which benefit from them (Environment Agency, 2006*b*). Flood warning symbols are used by the Environment Agency in its warning system to communicate the nature of the flood threat in a location and what residents should do (Environment Agency, 2011*d*): the flood symbols used as of 2011 have changed since the fieldwork for this project took place, however the aim of the symbols is the same. Flood responses assessed by the questionnaire also included changes to behaviour, including the discussion of flooding with other residents, and greater awareness of river levels and weather forecasts: these responses had been mentioned by interviewed residents.

Questions about flood hazard perception were also influenced by interview responses. The frequently mentioned contention that the 2005 flood was a 'one-off event' was included in the questionnaire. Additionally, comparisons of local (upper Ryedale) flood risk with floods occurring in other areas in the region (including York and Pickering) in interviews led to questionnaire respondents being asked to estimate the likelihood of flooding in Pickering, upper Ryedale, York and at their houses. Furthermore, respondents were asked whether or not flooding would occur more frequently in the future in Ryedale.

In order to assess residents' knowledge of past flooding in the catchment, a timeline was included on the first page of the questionnaire, asking residents to note floods which they could recall, and/or any floods which they had experienced themselves. The total number of floods recalled by respondents was used in the statistical analysis. In addition, floods recalled by respondents on the questionnaire timeline, and elsewhere within the questionnaire (including those in comments made by respondents), were noted and used in a reconstruction of past floods in the upper Rye catchment. In addition, the open-ended responses provided to the questions “What factors contributed to the flood in Ryedale in 2005? Has anything occurred to increase the risk of flooding?” were analysed and used in an analysis of the factors perceived to influence local flooding. Similarly, some questionnaire respondents provided reasons why they believed that at-risk residents, and/or local authorities were not prepared for a reoccurrence of flooding, and such responses were included in a further analysis. The results of these three analyses are included within Chapter 5.

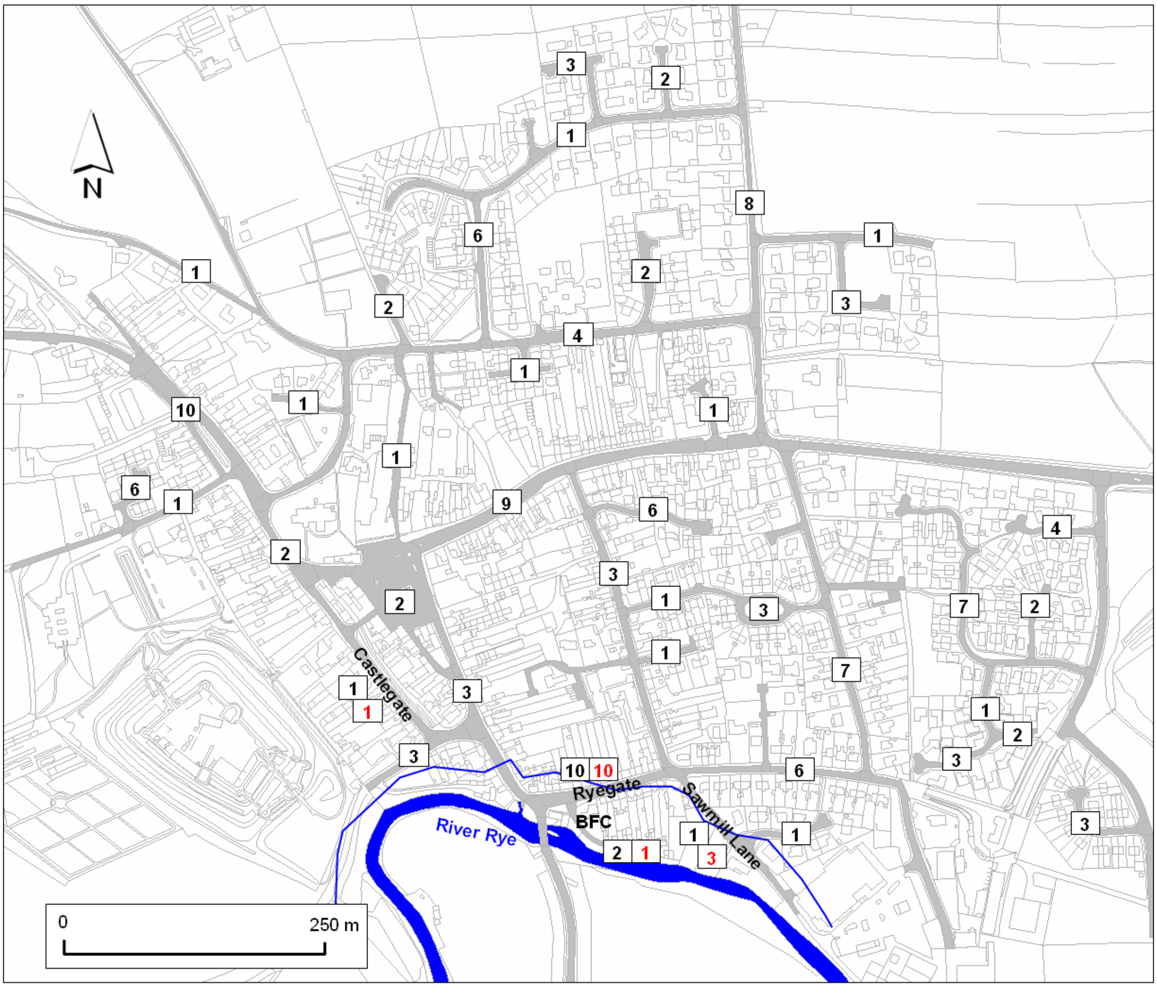
To collect information about perceptions of climate change, respondents were asked for their opinion on the 'wetness' of past decades, with possible responses for all decades from the 1930s to the 2000s. Similarly, respondents were asked whether the seasons of winter, spring, summer and autumn were getting wetter or drier, and if they felt that heavy, prolonged rainfall, intense thunderstorms and snowfall were occurring more or less often. These perceptions of changes to rainfall were also compared with the analysis of physical rainfall data described in Section 3.7.1, within a separate analysis (further information: Section 3.5), the results of which are presented in Chapter 4. The responses provided to two questions on the questionnaire (respondents were asked to recall the wettest years they could remember, and also days with a large amount of rainfall) were not used for a self-contained analysis, although comments made were noted if relevant to other questions.

Data collection for the questionnaire took place in Spring 2009. Initially, a pilot questionnaire was posted to 20 randomly selected addresses in Helmsley to assess response rates and question suitability. Following the receipt of these questionnaires, minor alterations were made to the form of the questionnaire. The questionnaire was sent out to all identifiable addresses in Helmsley in three batches. The first batch (400 questionnaires) was sent out to assess response rate, after this a second batch (398 questionnaires) was posted. A third batch of questionnaires (43 in total) was then sent to the area of Helmsley assessed by interviews (Ryegate, Bridge Farm Close and Sawmill Lane, Figure 3.4). In total, 156 responses to the questionnaire were assessed to be partially complete and used for analysis, giving a response rate of 18.5%. The locations of respondents who gave an identifiable address are shown in Figure 3.4.

The questionnaire sample of 156 is slightly below one tenth of the population of the town of Helmsley (1,610 people, estimated by Ryedale District Council in 2006, quoted in Helmsley Design Statement Working Group, 2008). A comparison of some of the demographic characteristics of respondents (Age, sex and household size) with census data summaries indicates that the questionnaire sample used in this study is older (by 11.6 years) and is more male than the population of Helmsley as a whole (Table 3.11). Although the average household size of respondents to the questionnaire is similar to that of Helmsley (ward), fewer households had children than in Helmsley overall, and over a third of sampled houses were one-person households, compared with 28% of houses within Helmsley as a whole (Table 3.11).

	Helmsley (ward)	Questionnaire sample	Notes
Age (mean)	52.3	63.9 Min: 23 Max: 92 n = 105	Helmsley ward mean based upon figures included in Ryedale District Council, 2007 (page 5), not including residents within 16-19 age group and assuming a maximum age of 92, based upon maximum age of responder in questionnaire survey.
Male/female (%)	48.2/51.8	56.3/43.8 n = 144	
One person households (%)	27.7	36.4	
House contains dependent children (%)	23.9	15.4	
Average household size (people)	2.2	2.0 n = 143	

Table 3.11: Summary of demographic characteristics of questionnaire respondents, with those of the population of the Helmsley ward. The Helmsley ward has a population of 3,111 and includes the town of Helmsley, almost all of the upper Ryedale area (including Hawnby and Rievaulx) as well as some small hamlets and villages in the upland areas near Helmsley. Data from Helmsley ward derived from the ward profile described by Ryedale District Council (Ryedale District Council, 2007), itself based upon data from the 2001 Census (Office for National Statistics).



KEY

River Rye

Extent of 2005 flash flooding (north bank of Rye only)

Roads, streets, residential areas

BFC Bridge Farm Close

Number of questionnaires received from street 6

Number of people interviewed from street 2

Figure 3.4: The location of questionnaire respondents and interviewees in Helmsley, indicating numbers of respondents from streets. The extent of the 2005 flash flood, shown adjacent to main areas of housing, is derived from Environment Agency post-flood survey data. Diagram contains Ordnance Survey MasterMap® data: © Crown Copyright/database right 2011. An Ordnance Survey/EDINA supplied service.

Information from received questionnaires was put into spreadsheet form and transferred to SPSS and coded. Two main methods were then used to assess the dataset:

- Descriptive statistics: summaries of the full dataset (Mayhew, 1997), with responses expressed generally as a percentage of all responses received.

- Non-parametric tests: "...methods of hypothesis testing and estimation that are valid under less restrictive assumptions than classical techniques" (Gibbons, 1993: 1), used to assess where statistically significant associations exist between variables.

In some cases, questionnaire respondents were given a Likert scale (a method of assessing and measuring attitude (Haddock and Maio, 2012)) to respond upon (e.g. Strongly agree, Agree, Neither agree nor disagree, Disagree, Strongly disagree). Due to the low number of responses in some of these categories, during analysis this scale was reduced to three variables (Agree, Neither agree nor disagree, Disagree) with responses in the more extreme categories combined with those in the 'Agree' and 'Disagree' response groups (Appendix 3).

The three non-parametric tests used during data analysis were the Chi-square test, the Kruskal-Wallis test, and the Mann-Whitney U test. The nature of the variables to be tested, and the number of groups associated with these variables, determined the type of test used in each case (Table 3.12). The specific nature of these statistical tests can be described thus: the Chi-square test is "...used to determine the significance of differences between two independent groups" (Siegel, 1956: 104), the Kruskal-Wallis test is used "...for deciding whether (more than two) independent samples are from different populations" (Siegel, 1956: 184) and the Mann-Whitney U test assesses "...whether two independent groups have been drawn from the same population" (Siegel, 1956: 116).

The nature of non-parametric tests offers clear benefits for an analysis of questionnaire data. Non-parametric tests "...do not make numerous or stringent assumptions about the population" (Siegel, 1957: 13) as parametric statistics do (Siegel, 1957): and "To assume that samples come from any specified family of distributions may be unreasonable" (Sprent and Smeeton, 2001: 3). Non-parametric methods are "...widely used for analysing social science data which... may be severely skewed" (Chatfield, 1988: 50). Additionally, non-parametric statistics can assess data which is not numerical, for instance data in ranks or classifications (Siegel, 1957). Furthermore, "Probability statements obtained from most non-parametric statistical tests are *exact* probabilities" (Siegel, 1957: 18, emphasis as in original).

Non-parametric tests do assume random samples, and independent observations (Pallant, 2001). With regards to the questionnaire data assessed in this thesis, the sample was, in effect, a self-selecting one. Questionnaires were sent out to all identified addresses in Helmsley, and receiving questionnaire responses was dependent upon individuals filling in the questionnaire and returning it to the researcher, who in turn had no control over this process. It can be argued that the sample assessed by this questionnaire was as random as possible under the conditions and methods of the research. Additionally, it has been noted that "...a strictly random sample is a very rare species" in data collection (Tanenbaum and Scarbrough, 1998: 16).

Test	Used when
Chi-square	"Two categorical variables, with two or more categories in each" ([1])
Mann-Whitney U	"...one categorical variable with two groups", and "...one continuous variable" ([2])
Kruskal-Wallis	"...one categorical independent variable with three or more categories", and "...one continuous dependent variable" ([3])

Table 3.12: Non-parametric tests used in the questionnaire data analysis, and the conditions for using them. Adapted from Pallant, 2001: [1] - page 257, [2] - page 260, [3] - page 263.

A cross table of all variables in the dataset was therefore formed, with relevant non-parametric tests (Table 3.12) applied to the variables. Those tests which returned a p-value (asymptotic significance) lower than 0.05 were noted. The p-value represents "...the probability that any particular outcome would have arisen by chance" (Greenhalgh, 1997: 423). A p-value of 0.05 suggests that the statistically significant association between variable responses did not occur due to chance, at the 95% confidence level. For chi square tests, test results where more than 20% of cells had expected frequencies of lower than five were removed, as the chi square assumes a minimum cell count greater than five (Pallant, 2001). Additionally, where a 2 x 2 analysis table was involved in a chi square calculation, the Yates' Correction for Continuity value was given instead of the usual chi square value. This correction value "... is designed to correct or compensate for what some writers feel is an overestimate of the chi-square value when used with a 2 by 2 table" (Pallant, 2001: 257).

Following a collection of all statistically significant test results, those results that involved variables associated with flood response and hazard perception were listed for further investigation. Statistically significant test results were then explored further using cross tables, in order to identify the nature of the association between the variables. This assessment was made subjectively based upon the nature of positive and negative value changes. For example, Table 3.13 shows a cross table which was assessed as the chi-square result was statistically significant ($\chi^2 = 4.968$, $p = 0.026$). In this example, those respondents involved with the cleanup following the flash flood in 2005 were more likely to know what Floodline is. Where the nature of the association between the variables was interpreted to be indeterminate or unclear, the statistically significant test result was noted, but not taken into account for analysis. Following the completion of this further analysis, the variables which have statistically significant associations with flood response and flood risk perception could be assessed. An extract from this analysis is shown in Table 3.14.

		Knowledge of the Floodline warning service	
		Does not know what it is (%)	Knows what it is (%)
Involvement with cleanup following 2005 flood?	No	56	44
	Yes	31	69

Table 3.13: An example of cross table analysis to investigate the nature of a statistically significant association between variable responses. Percentages in the table indicate the proportion of respondents answering "No" and "Yes" to the variable on the left of the table who gave particular responses to the question/variable on the top row of the table.

	Knowledge of Environment Agency services		
	Warning symbols	Floodline	Flood risk maps
As respondents get older:		↓ M-W U U = 694 n = 93 p = 0.004	
If there are children living at home (rather than no children):		↑ Chi square χ^2 = 4.316* df = 1 n = 128 p = 0.038 ex = 0, 9.84	
If there is more than one adult living at home (rather than just one):		↑ Chi square χ^2 = 5.650* df = 1 n = 128 p = 0.017 ex = 0, 22.03	↑ Chi square χ^2 = 5.442* df = 1 n = 125 p = 0.02 ex = 0, 18.66

Table 3.14: An example of part of the analysis for three flood response variables (all related to knowledge/awareness of the Environment Agency's services). This is not the complete analysis, but is a small extract of part of the table. Arrows indicate changes to the likelihood of the flood response variables, based upon the description of the changes to the variable in each row. Grey boxes signify a statistically significant association between two variables, with greater than 95% confidence. Blue boxes signify a statistically significant association with over 99% confidence. Other information within cells includes information about the statistical test used and its results, described further alongside the full tables in Chapter 5.

A limitation of statistical analyses is the fact that statistical correlations between two variables do not reveal causality (Greenhalgh, 1997). In this questionnaire analysis, just because a statistically significant assocation was discovered, it did not mean that variable 'x' causally affects variable 'y'. However, the use of both quantitative (questionnaire) and qualitative (interview) data means that 'deeper' and more detailed questioning (how? and why?) and findings from interviews could be used to support inferred relationships between variables from the questionnaire data analysis. While the interview data is based on a smaller numerical sample, its findings were clearly useful in the discovery of the reasons why certain factors appear to influence hazard response and perception, and the interviews were also used to assess responses to flash flooding by a defined population of people (those directly affected by flash flooding in 2005).

3.9 Chapter summary

Following the recognition of the importance of the upland flash flood issue, and associated research requirements (Sections 1.4, 2.7) and the overall thesis aim and objectives (Section 1.4), this methodology chapter has described and justified the methods used to carry out the necessary research into these areas. Firstly, this methodology chapter described two central concepts that underpin this thesis: interdisciplinarity, and the natural hazards framework. The natural hazards framework of integrating analyses of physical and human systems is paramount in this thesis, as is the use of both local and institutional knowledge alongside physical data collection. The collection of both quantitative and qualitative data to investigate the objectives of this research project is also central to this research. Methods of data collection, and integration of physical/human and qualitative/quantitative data are also outlined in this methodology. The chapter structure of the thesis has also been outlined, linking clearly with the structure of data collection and the initial objectives of the thesis.

Chapter 4

Reconstructing long-term upland rainfall records

This chapter aims to assess changes to heavy rainfall in an upland area, in order to place the rainstorm which occurred on the 19th June 2005, and caused flash flooding in upper Ryedale, into a longer-term context. Due to the typical seasonality of heavy rainfall events, and the seasonality of flash flood occurrences (e.g. Merz and Blöschl, 2003; Section 1.2), changes in summer heavy rainfall strongly influence flash flood risks. An analysis of three data sources is undertaken within this chapter. The first is an analysis of officially-collected rainfall data from upper Ryedale, which has been formed into a composite record running from 1916 to 2009 (Section 4.1). The rainfall patterns found in this analysis are then compared with other long-term records in the region and an England and Wales record (Section 4.2). Additionally, a summary of privately collected rainfall records from two residents in the upper Ryedale area is compared with the official rainfall series (Section 4.3). Finally, an assessment is made of residents' perceptions of changes to local rainfall (Section 4.4). The chapter concludes with a summary of its main findings (Section 4.5). As well as assessing changes to heavy rainfall in upper Ryedale, the chapter also evaluates the extent to which the past climate (with regards to rainfall and heavy rainfall) of an upland area can be reconstructed using proxy records.

The formation and composition of the upper Ryedale rainfall series was described in Section 3.7.1. The upper Ryedale rainfall series is derived from data recorded by the Met Office, and downloaded from the Met Office MIDAS Land Surface Stations database (National Centre for Atmospheric Science, British Atmospheric Data Centre, 2006). Further information about other rainfall series analysed in this chapter is also included in Section 3.7.1. The England and Wales Precipitation Series, and other regional rainfall series analysed, were downloaded from the Met Office Hadley Centre website (download page: http://www.metoffice.gov.uk/hadobs/hadukp/data/download.html, dataset reference: Alexander and Jones, 2001). Acknowledgements of the use of the Durham Observatory record, privately maintained rainfall records (Helmsley and Sproxton) and other rainfall information and sources of data are made clear in table and figure captions, and the chapter text, where appropriate. Details of statistically significant relationships discovered within this rainfall analysis (p-value < 0.05) are included in Appendix 4 at the end of this thesis. Such relationships are marked in the text with an asterix (*).

4.1 Assessment of rainfall data

The composite rainfall record used for the following analysis is that defined in the methodology (Section 3.7.1), with the locations of the rain gauges used in the construction of the series shown in Figure 3.2. A previous version of the rainfall analysis of this data series, complete up to August 2009, was presented in Hopkins et al. (2010). Section 4.1.1 presents a short summary of annual and seasonal rainfall patterns, prior to a central analysis of heavy rainfall. This includes an assessment of the most extreme rainfalls within the rainfall record, including annual and seasonal maxima (Section 4.1.2) and a further assessment of above-threshold heavy rainfall (Section 4.1.3).

4.1.1 Annual and seasonal rainfall totals

Normalised annual rainfall totals (average = 100) show that the year 2000 is the wettest year on record at upper Ryedale (135.6). Four of the ten wettest years on record have occurred since 1999, however, five of the ten occurred prior to 1961, showing a wide distribution of wet years throughout the record. The long-term ten year running mean of normalised annual rainfall totals (Figure 4.1) shows no marked trends across the entire 1916-2009 rainfall record for upper Ryedale. However since 1961 (to 2009) there has been a general increase in annual rainfall totals which is statistically significant at the 95% confidence level (p-value = 0.04)*. The record shows four wet periods with clusters of years with above average rainfall: the late 1920s and 1930s, the 1950s, the late 1970s and 1980s and late 1990s to 2009. Decadal averages of normalised annual rainfall totals (Table 4.1) show that the 2001-2009 period (although not a complete decade) has the highest mean normalised total on record, followed by the 1930s. The 1960s were the driest complete decade in the record, closely followed by the 1970s.

Period	**Annual**	Winter	Spring	Summer	Autumn
1916-1920	**93.8**	72.0	111.2	96.8	83.5
1921-1930	**97.7**	98.6	92.3	97.9	100.0
1931-1940	**105.9**	109.6	107.0	95.3	112.0
1941-1950	**98.5**	98.3	103.4	96.4	96.0
1951-1960	**101.1**	97.6	91.7	112.0	100.2
1961-1970	**96.2**	91.0	95.0	101.7	97.2
1971-1980	**96.9**	106.0	94.7	90.9	95.7
1981-1990	**100.8**	94.2	107.1	100.8	99.8
1991-2000	**99.8**	102.3	103.0	82.6	109.7
2001-2009	**107.4**	105.8	96.8	131.1	98.6

Table 4.1: Decadal averages of normalised annual and seasonal rainfall totals, upper Ryedale, 1916-2009. Rainfall series formed from data contained in the Met Office MIDAS database.

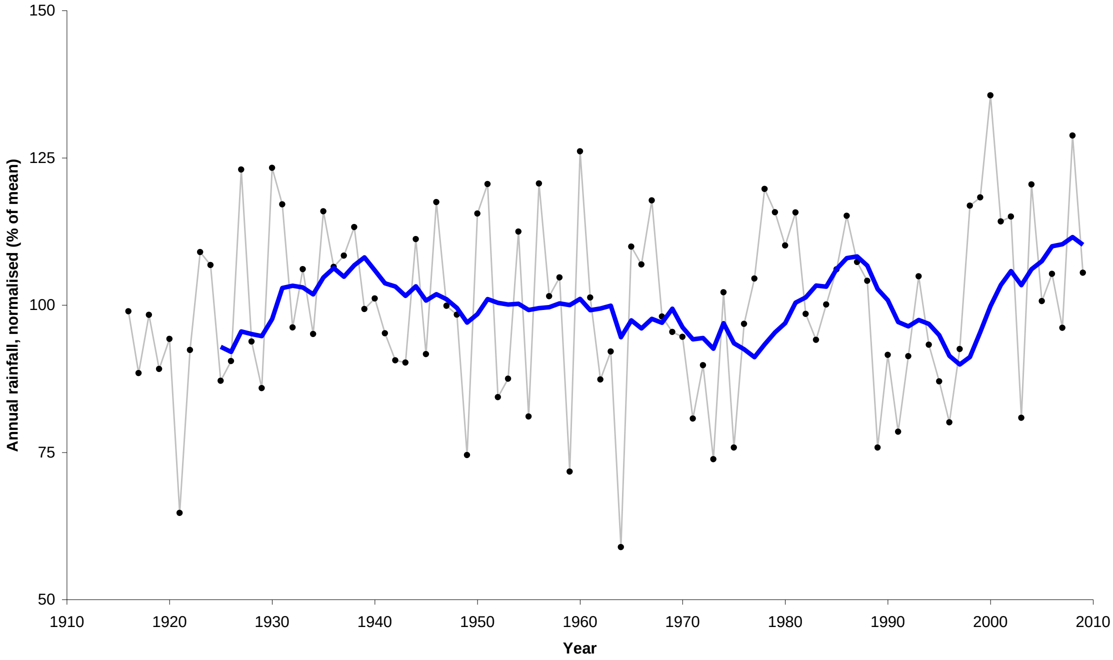


Figure 4.1: Normalised annual rainfall totals recorded at upper Ryedale, 1916-2009, showing ten year running mean. Rainfall series formed from data contained in the Met Office MIDAS database.

An analysis of normalised seasonal rainfall totals shows a clustering of wet summers from 2001 onwards (Table 4.1); prior to this period, earlier decades (the 1970s and 1990s) saw very below average summer totals (Table 4.1). The years 1997, 2004, 2007, 2008 and 2009 are within the ‘top ten’ wettest summers of the 1916-2009 record. If winter and summer rainfall totals are directly compared using a ratio (Figure 4.2), the ratio has increased from approximately 1960 to the early 2000s, suggesting that winter rainfall totals have increased relative to summer totals. This increase is slightly outside of statistical significance at the 95% confidence level (1961-2000, $p = 0.14$). By contrast, from c. 2003 onwards, a number of very wet summers have led to a sharp fall in the winter:summer ratio.

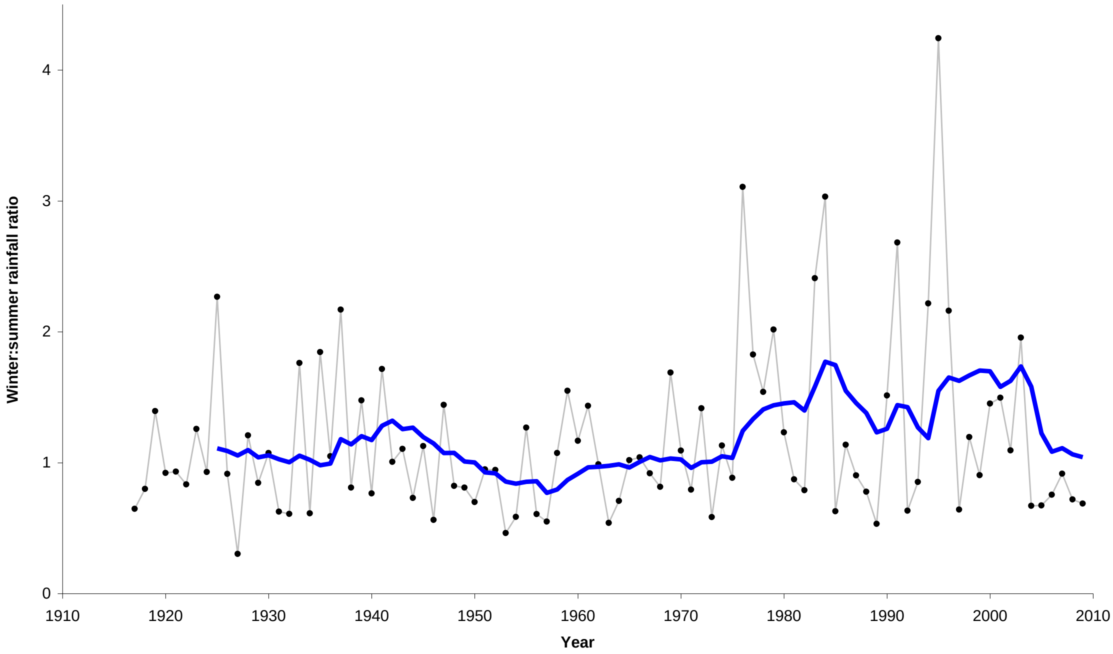


Figure 4.2: Winter:summer rainfall ratios at upper Ryedale, 1916-2009, showing ten year running mean. Rainfall series formed from data contained in the Met Office MIDAS database.

4.1.2 Extreme and maximum rainfalls

The highest daily rainfalls recorded annually for the 1916-2009 period are shown in Figure 4.3, and Table 4.2 details the ten highest daily rainfall totals recorded. In total, 14 years between 1916 and 2009 recorded daily rainfall totals above 50 mm, and four years recorded daily rainfall totals above the 19th June 2005 rainfall total of 69.6 mm (Table 4.2). From the 1960s onwards, annual maximum falls have increased (Figure 4.3), although this increase is not statistically significant (1961-2009, $p = 0.31$). From a period of low maxima in the early 1990s (between 1990 and 1996, the maximum daily rainfall recorded was 39.9 mm) a cluster of very high maximum daily rainfalls occurred in the late 1990s and 2000s, including the 19th June 2005 rainfall and the heaviest daily accumulation on record (87 mm) in 2002, in addition to two other falls of 67.6 mm and 53.7 mm in 1997 and 2000.

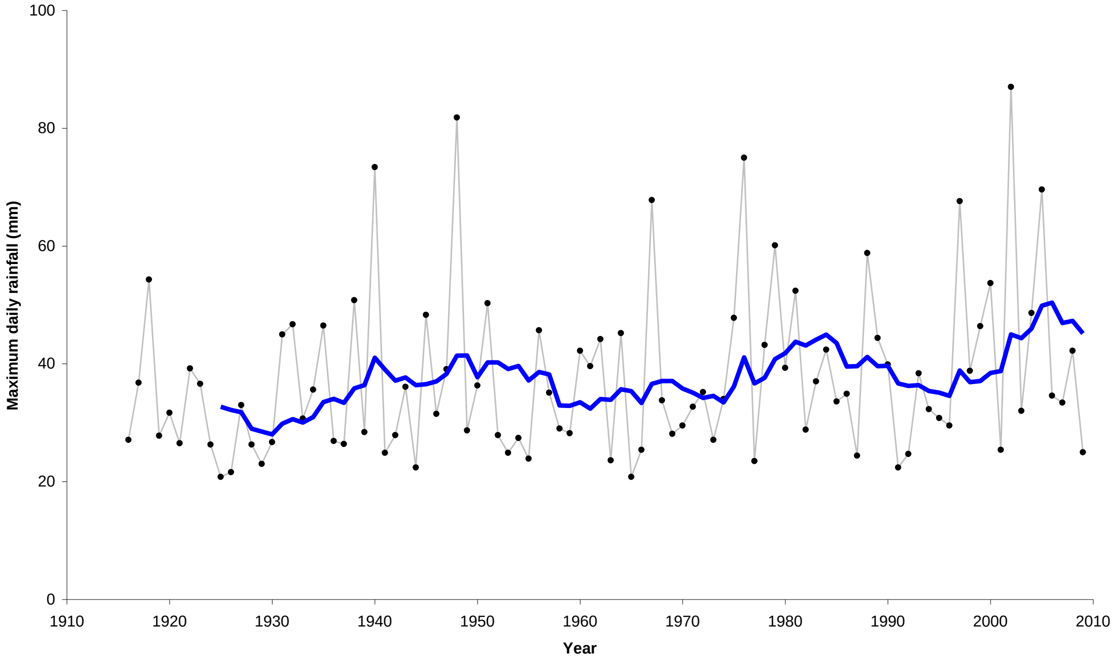


Figure 4.3: The maximum daily rainfall recorded annually at upper Ryedale, 1916-2009, showing ten year running mean. Rainfall series formed from data contained in the Met Office MIDAS database.

Date	Rainfall (mm)
1st August 2002	87.0
2nd June 1948	81.8
11th September 1976	75.0
17th July 1940	73.4
19th June 2005	**69.6**
5th November 1967	67.8
31st August 1997	67.6
28th March 1979	60.1
30th June 1988	58.8
21st May 1918	54.3

Table 4.2: The ten highest daily rainfall totals recorded in upper Ryedale, 1916-2009, with the day of the major flash flood marked in bold. Rainfall series formed from data contained in the Met Office MIDAS database.

Heavy rainfall in summer tends to be more extreme than heavy rainfall in other seasons: six out of the ten highest daily rainfalls on record in upper Ryedale have fallen in summer (Table 4.2). Of the 50 largest daily rainfall totals, nearly half (24) of them occurred in summer. Meanwhile, heavy rain days in winter tend to be much less extreme:

the highest daily rainfall total recorded in winter is 43.2 mm. 15 days in summer, eight spring days and eight autumn days in the whole record recorded a higher rainfall than this.

The highest daily rainfall totals recorded in each season throughout the 1916-2009 record are shown in Figure 4.4. It is notable that maximum falls in all seasons have generally increased since c. 1960, although winter rainfall maxima have declined slightly after the 1990s. Meanwhile, there has been an increase in summer maximum daily rainfall totals since 1960 which lies just outside of statistical significance (1961-2009 period, $p = 0.07$), with some particularly high maximum falls in recent years, including five maximum daily falls in excess of 40 mm since 1997. Over the same period, the highest winter maximum fall was just 33 mm (in 2003): the heaviest winter maximum rainfall (43.2 mm) occurred in 1979. From 1984 to 1991, five winter maximum falls exceeded 30 mm; however since 1991, only two winter maxima have been greater than 30 mm, reinforcing the fact that winter heavy rain days tend to be less extreme than those in other seasons. Two spring maximum falls exceeded 40 mm in 1999 and 2000, the latter year also saw a 53.7 mm maximum daily fall in autumn. Autumn also saw a high daily rainfall total above 40 mm in 2008.

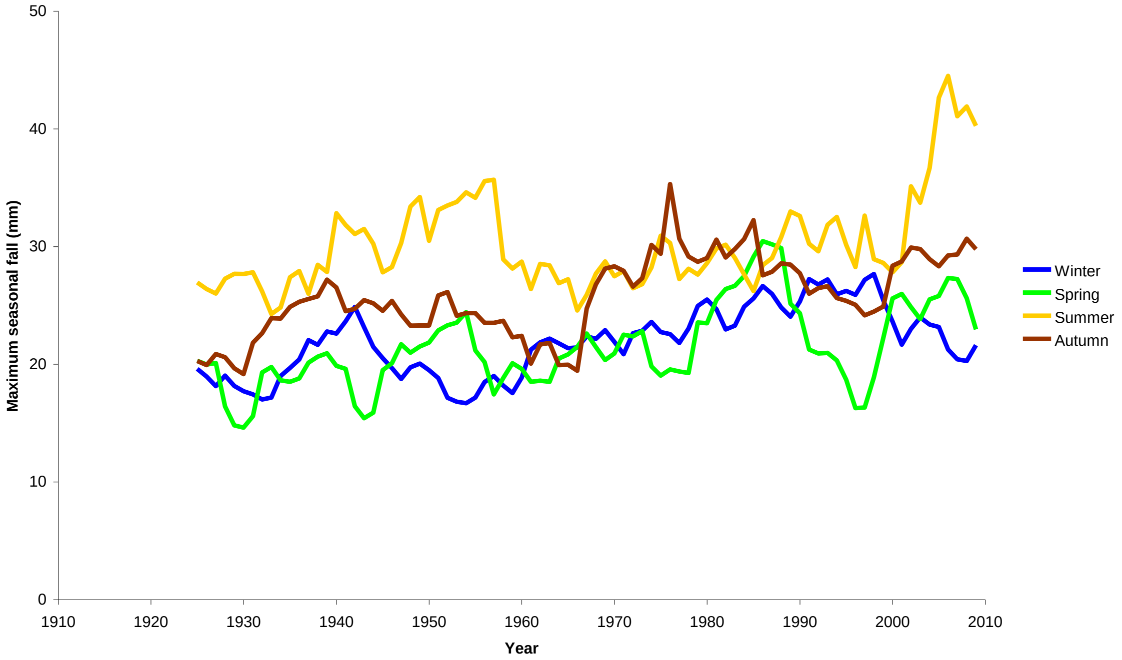


Figure 4.4: The maximum daily rainfall recorded in each season at upper Ryedale, 1916-2009, showing ten year running means. Rainfall series formed from data contained in the Met Office MIDAS database.

While the past history of daily rainfall totals in upper Ryedale shows that the 19th June 2005 rainfall has been exceeded by other daily rainfall totals (Table 4.2), available rainfall records from the wider North York Moors upland area also show that rainfall events have occurred which exceed the 19th June 2005 event in terms of total rainfall accumulation, and peak intensity (Figure 4.5). Daily rainfall totals in excess of 100 mm have been recorded at other rain gauges in the area, including falls of 114.6 mm at Fylingdales on the 1st August 2002 and 145 mm at Kildale East Green Beck on the 11th September 1976: other rain gauges also recorded daily totals of over 100 mm during this rainfall event (rainfall data source: Met Office MIDAS database, National Centre for Atmospheric Science, British Atmospheric Data Centre, 2006). In terms of rainfall intensity, a summer thunderstorm at Carlton-in-Cleveland on the 10th August 2003 led to a fall of 47.7 mm in 20 minutes, with 30 mm falling in five minutes (Cinderey, 2003), this latter rainfall intensity is the highest at that duration recorded in the British Isles (Burt, 2003). The maximum 15 minute accumulation during this storm (49.1 mm) greatly exceeded the comparative figure at Hawnby on 19th June 2005 (26.8 mm). Therefore, while the 19th June 2005 rainfall event was clearly an extreme event, and the response of the upland catchment to the rainfall was unusual (Wass et al., 2008), rainfall events with large daily accumulations, and/or high peak intensities occur more routinely at longer timescales in upland areas.

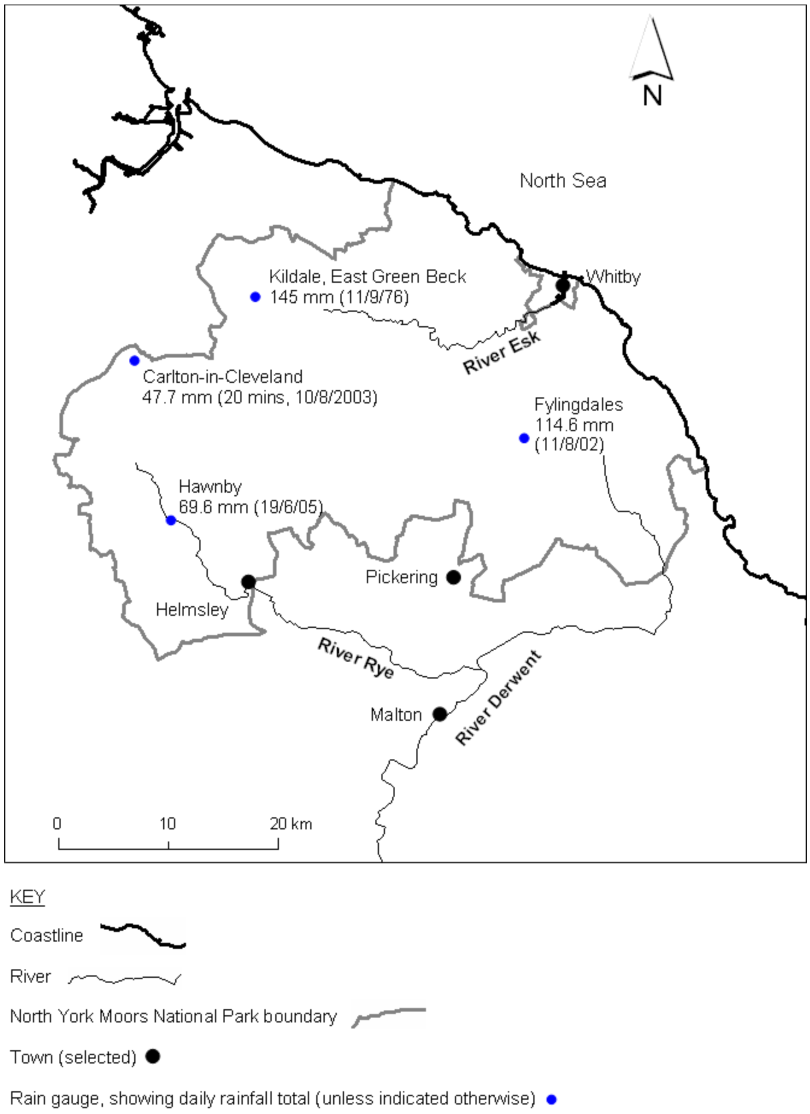


Figure 4.5. Recorded extreme rainfall events in the North York Moors area. Diagram contains Ordnance Survey Strategi® data: © Crown Copyright/database right 2011. An Ordnance Survey/EDINA supplied service. Rainfall data sources: Met Office MIDAS database and Cinderey (2003) for Carlton-in-Cleveland rainfall.

4.1.3 Annual and seasonal trends in heavy rainfall

Figure 4.6 shows the changes in the annual frequency of heavy rain days (above the DR1 threshold) in upper Ryedale between 1916 and 2009, and changes to the proportion of annual rainfall falling on heavy rain days over the same period. A similar pattern to the annual rainfall totals (Figure 4.1) emerges, showing distinct periods with relatively high frequencies of heavy rain days and a large contribution of heavy rainfall to annual rainfall, as well as a general increase in heavy rainfall since the 1960s, although the increase in the frequency of heavy rain days from 1961-2009 lies just outside of statistical significance ($p = 0.11$). Decadal frequencies of heavy rain days show that the 1960s have the lowest number of heavy rain days of any complete decade (Table 4.3). Since the 1960s there has been a steady increase in the frequency of heavy rainfall to the 1990s (Figure 4.6, Table 4.3); however, the overall frequency of heavy rainfall was higher in the 1930s (50 heavy rain days) than in any other period in the record. A similar pattern is found for the proportion of annual rainfall falling on heavy rain days - this was lowest in the 1960s and highest in the 1930s. From the 1960s to present, the proportion of annual rainfall falling on heavy rain days has generally increased (Figure 4.6) although decadal means from the 1970s to the 2001-2009 period have not changed dramatically (Table 4.3).

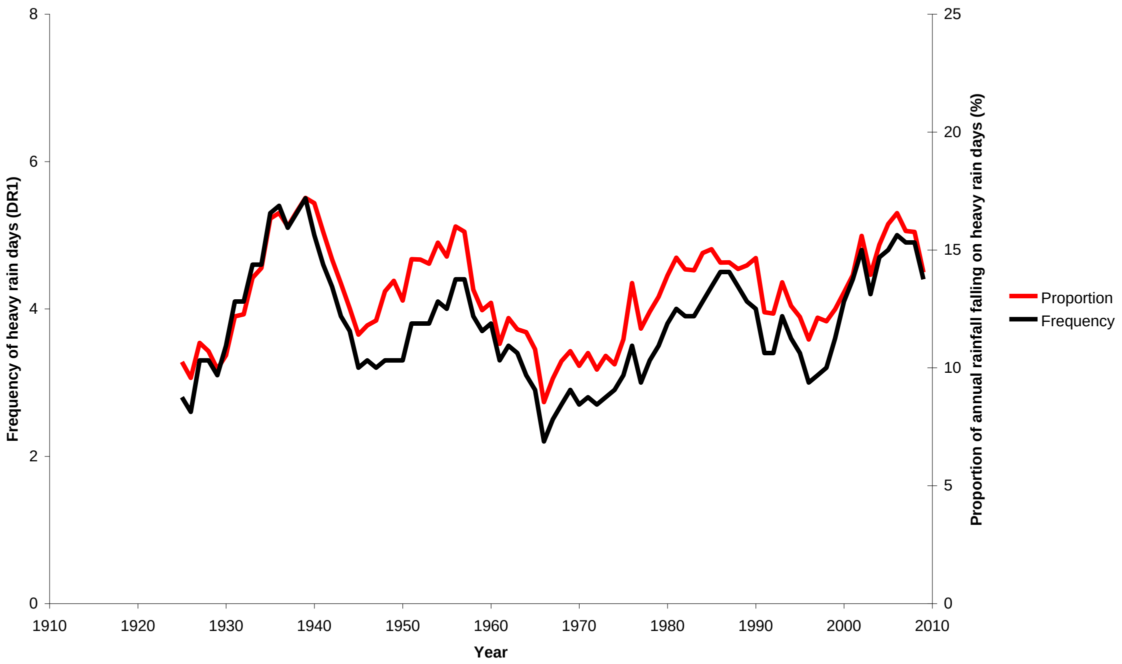


Figure 4.6: The annual frequency of heavy rain days (as defined by the DR1 threshold) and the proportion of annual rainfall falling on heavy rain days, upper Ryedale, 1916-2009. Graphs show ten year running means. Rainfall series formed from data contained in the Met Office MIDAS database.

Period	Frequency of heavy rain days	Proportion of annual rainfall falling on heavy rain days (%)
1916-1920	15 (3)	11.4
1921-1930	35	11.3
1931-1940	50	17.1
1941-1950	33	12.7
1951-1960	38	13.7
1961-1970	27	10.0
1971-1980	38	14.1
1981-1990	40	14.7
1991-2000	41	14.4
2001-2009	35 (3.9)	13.1
Mean	37.8	13.4

Table 4.3: Heavy rain day frequency and the mean proportion of annual rainfall falling on heavy rain days (as defined by the DR1 threshold) in upper Ryedale, 1916-2009. Figures in brackets indicate the average frequency of events per year in 'incomplete' decades (1916-1920, 2001-2009). Additionally, the mean frequency of events per decade does not include these incomplete decades. Rainfall series formed from data contained in the Met Office MIDAS database.

Notably, heavy rain days in the upper Ryedale series occur much more frequently in summer (36% of all heavy rain days) and autumn (32%) than in winter (18%) or spring (14%). Furthermore, a larger proportion of summer rainfall falls on heavy rain days than in other seasons. From 1916 to 2009, 19.8% of all summer rainfall fell on heavy rain days, compared with 15.3% of autumn rainfall, 9.5% of spring rainfall, and just 8.3% of winter rainfall (Table 4.4).

Because 44% of all three month seasons in the full 94 year record did not record any heavy rain days at all, it is best to use decadal totals and averages of heavy rainfall events to analyse changes in the seasonal frequency, and contribution to total rainfall, of heavy rain days over time (Table 4.4). Particularly high numbers of winter rain days were recorded in the 1930s and 1970s. However while the 1990s also recorded an above average number of winter rain days, in the nine years from 2001 only three heavy rainfalls have been recorded in winter. Heavy rainfalls in summer meanwhile have seen a general decline from the early to mid-20th century to the end of the record. The 1950s saw most heavy rain days in summer (19) and summers in the four decades from 1921-1960 recorded 62 heavy rain days in total, while in the four decades from 1961-2000, only 40 heavy rainfalls were recorded in summer. However, the nine years from 2001 observed 18 heavy summer rainfalls (one less than the 1950s figure), reflecting a sharp increase from the 1990s where only seven heavy summer rain days were recorded (the lowest total in any complete decade).

Meanwhile, decadal frequencies of heavy rain days in spring have not varied greatly over much of the record, however the 1980s and 1990s recorded 19 heavy rain days in spring between them, only two fewer heavy rain days than the total number of spring heavy rain days recorded from 1931-1980. The 2001-2009 period, while incomplete, has seen four heavy rainfalls in spring which suggests a return to average values. The highest number of autumn heavy rain days occurred in the 1930s (20 heavy rain days), although all other decades prior to 1950 saw below average frequencies of heavy rainfall. Since 1960, the numbers of autumn heavy rain recorded are close to the average decadal frequency. Although the 1990s recorded a high total of 17 events, the 2001-2009 period has seen a near-average frequency of heavy rainfall in autumn.

As well as decadal frequencies of heavy rain days, the proportion of seasonal rainfall falling on heavy rain days has varied considerably over the 1916-2009 period (Table 4.4). However similar trends to the frequency data exist, including a sharp increase in the contribution of heavy rainfall to summer rainfall from the 1990s to the 2000s, with heavy rainfall accounting for over a quarter of all summer rainfall between 2001 and 2009, the highest percentage of any summer period. At the same time the proportion of total winter rainfall falling on heavy rain days was above average in the 1970s and 1990s, but has declined to its lowest level (3.8% of all winter rainfall) across the whole record in the 2001-2009 period. Figure 4.7 shows these seasonal changes graphically, and while there are no statistically significant trends in the proportion of seasonal rainfall falling as heavy rainfall for any season (over both the 1916-2009 and 1961-2009 periods) it is evident that the contribution of heavy rainfall to winter rainfall totals has generally increased from the 1940s to late 1990s. Meanwhile, the summer running mean has remained well below its 1950s peak. However, since c. 2000, there has been a marked decline in the contribution of heavy rain days in winter (the ten year running mean reaching its lowest value), and a sharp rise in the proportion of summer rainfall contributed by heavy rain days (Figure 4.7). From 1991-2009, the increase in the proportion of summer rainfall contributed by heavy rain days is very slightly outside of statistical significance at the 95% confidence level ($p = 0.052$).

Heavy rain day contributions to spring and autumn rainfall have been much more variable (Figure 4.7). The proportion of spring rainfall falling on heavy rain days has two prominent peaks in the 1980s and after 2000, with a sharp decline in spring heavy rain days in between these peaks in the 1990s. The contribution of autumn heavy rain days to seasonal rainfall has also been varied, although there has been a general increase in contribution from the 1960s to the end of the record.

	Frequency of heavy rain days				Proportion of seasonal rainfall falling on heavy rain days (%)			
Period	Win	Spr	Sum	Aut	Win	Spr	Sum	Aut
1916-1920	1	3	6	5	3.9	12.5	15.4	14.0
1921-1930	8	3	18	6	9.1	5.0	21.7	7.1
1931-1940	10	7	13	20	12.0	11.9	21.3	22.0
1941-1950	6	3	12	12	7.5	7.8	18.5	15.8
1951-1960	5	5	19	9	6.3	9.7	23.5	11.8
1961-1970	4	3	9	11	5.6	4.8	13.2	15.2
1971-1980	11	3	10	14	12.5	6.6	16.5	19.7
1981-1990	5	9	14	10	7.9	13.6	22.6	12.3
1991-2000	9	10	7	17	10.7	15.9	14.4	19.3
2001-2009	3	4	18	10	3.8	6.4	25.6	13.5
Mean	7.3	5.4	12.8	12.4	8.3	9.5	19.8	15.3

Table 4.4: Decadal totals of heavy rain days (as defined by the DR1 threshold) falling in each season in upper Ryedale, and the decadal proportion of seasonal rainfall falling on heavy rain days, upper Ryedale, 1916-2009. Note that 1916-1920 and 2001-2009 are not complete decades. Decadal means of heavy rain day frequency are calculated using complete decades only, the mean proportion of seasonal rainfall falling on heavy rain days is calculated using the entire record. Rainfall series formed from data contained in the Met Office MIDAS database.

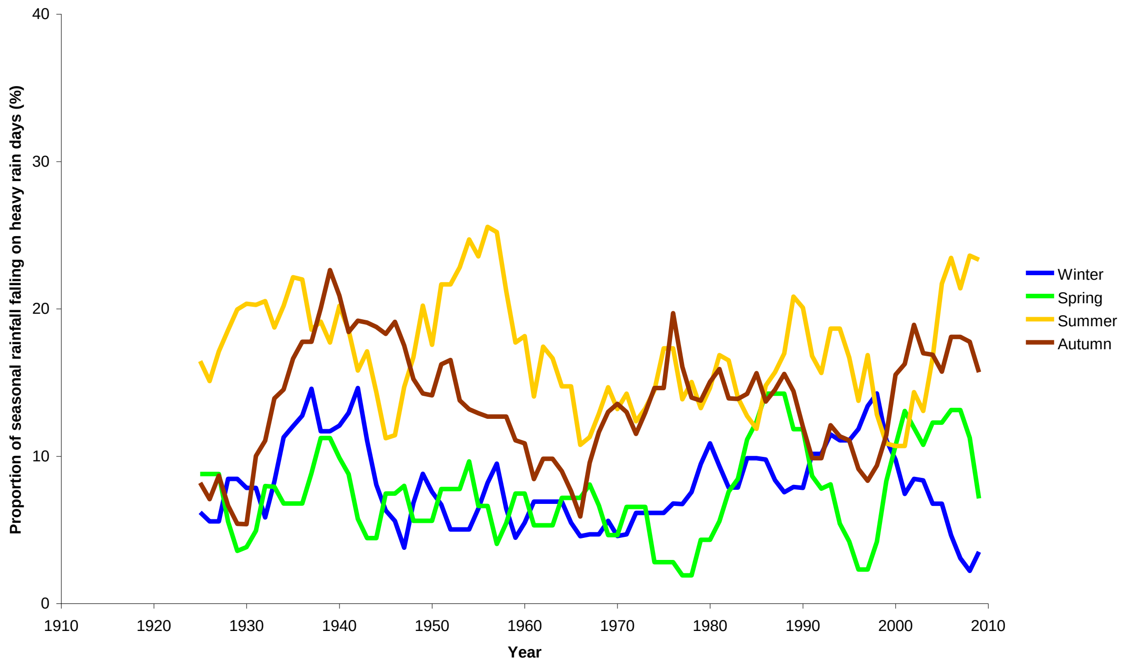


Figure 4.7: Changes in the proportion of seasonal rainfall falling on heavy rain days for winter, spring, summer and autumn, upper Ryedale, 1916-2009. Heavy rain days defined using the DR1 threshold. Lines show ten year running means. Rainfall series formed from data contained in the Met Office MIDAS database.

4.2 Comparison of local trends with heavy rainfall patterns observed regionally, and in England and Wales

In order to assess whether heavy rainfall patterns observed at upper Ryedale are apparent at larger spatial scales, two other long-term rainfall records are analysed and assessed below. A second rainfall record from the north-east of England, that from the Durham University Observatory, is analysed from 1901-2009. Also, the daily rainfall values available from the England and Wales Precipitation Series available from the Met Office Hadley Centre website (download page: http://www.metoffice.gov.uk/hadobs/hadukp/data/download.html, dataset reference: Alexander and Jones, 2001) from 1931 onwards are also assessed. Additionally, annual and seasonal rainfall totals are available for the England and Wales series prior to 1931 and are also analysed from 1901 onwards. Overall there are strong, statistically significant correlations between the annual rainfall totals recorded in the upper Ryedale and Durham series (coefficient = 0.78)* as well as with the England and Wales series (coefficient = 0.76)* (1916-2009 period in both cases). To assess heavy rainfalls, the DR1 heavy rainfall threshold (as described within Section 3.7.1; the rainfall value exceeded on 1% of all days in the record, as used to analyse the upper Ryedale record) is used. For the Durham series, the DR1 threshold was calculated for daily values between 1916 and 2009, corresponding to the period of analysis for the upper Ryedale series. For the England and Wales series, this threshold was calculated between 1931 and 2009. The threshold values are 19 mm (Durham) and 15.8 mm (England and Wales).

Annual heavy rainfall patterns at Durham and in the England and Wales series, assessed in terms of the proportion of annual rainfall falling on heavy rain days, show a general increase since the middle of the 20th century, in common with the upper Ryedale series (Figure 4.8). The ten year running means of the Durham and upper Ryedale series show more variation than the England and Wales series, due to the fact that the latter series is averaged (Alexander and Jones, 2001). However, heavy rainfall has clearly increased across the whole country, as the increase since the 1960s in the England and Wales series is slightly outside of statistical significance at the 95% level (1961-2009 period, p-value = 0.12). The Durham running mean has a peak in the late 1960s which is not present in the upper Ryedale series, making the overall increase in the contribution of heavy rainfall to annual rainfall since the 1960s less strong at Durham than it is at upper Ryedale. However all three series show a clear increase in heavy rainfall from the 1990s to the 2000s (Figure 4.8).

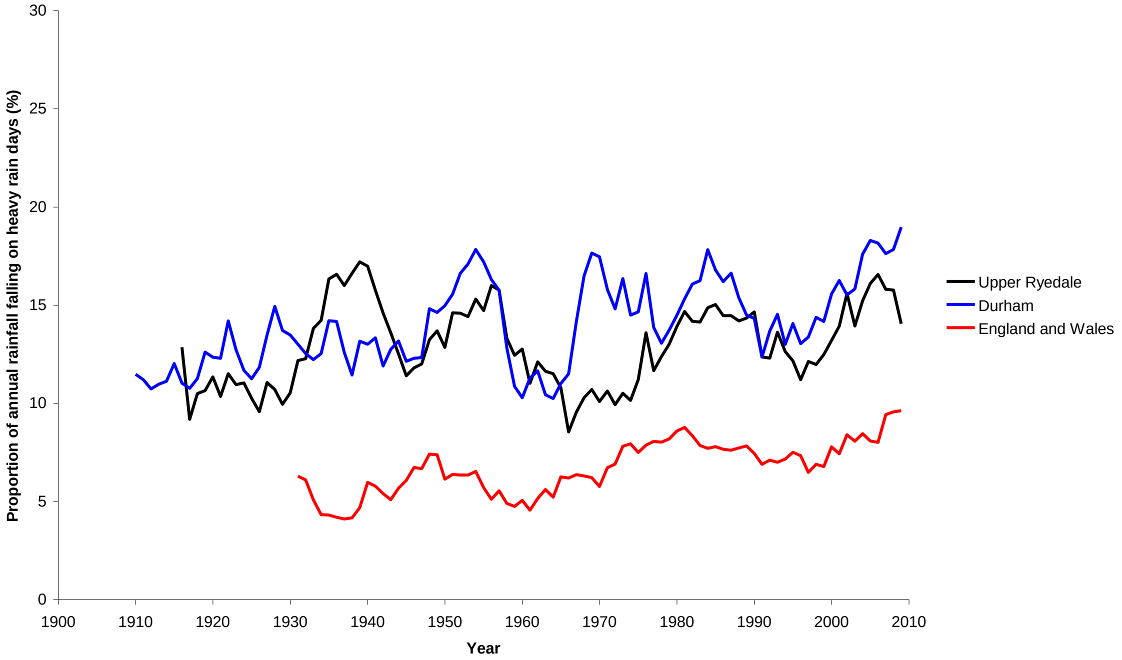


Figure 4.8: The proportion of annual rainfall falling on heavy rain days in the upper Ryedale, Durham and England and Wales rainfall series. Heavy rain days defined using the DR1 threshold, calculated at Durham for the 1916-2009 period of the record. Lines show ten year running means. Upper Ryedale rainfall series formed from data contained in the Met Office MIDAS database. England and Wales Precipitation Series downloaded from the Met Office Hadley Centre website. England and Wales Precipitation Series data: © Crown Copyright 2011, dataset reference: Alexander and Jones, 2001. Durham rainfall data provided by Professor Tim Burt.

There are some clear contrasts between upper Ryedale and the regional and England and Wales pictures in terms of the seasonality of heavy rainfall. When the most extreme daily rainfall totals are assessed (the heaviest 50 daily falls on record) summer heavy rainfall events dominate at upper Ryedale (Table 4.5). However the proportions of autumn and summer extreme events are similar at Durham, and more than half of the 50 highest rainfall totals in the wider England and Wales series were recorded in autumn, as opposed to just one in five events in summer (compared with approximately one in two at upper Ryedale and two in five at Durham) (Table 4.5). Similarly, at upper Ryedale and Durham, the less extreme DR1 heavy rain days (Table 4.6) have occurred mainly within summer and autumn, with summer having the largest proportion. However, for the England and Wales series, almost half of all heavy rain days occurred in autumn, while winter records a similar proportion of heavy rain days to summer (Table 4.6). Therefore, across the U.K., it appears that autumn, rather than summer, is the season where most heavy rainfalls occur. The differences in seasonal distributions are likely to result from two factors. The first is that upper Ryedale, and Durham, are situated in the north-east of England and are therefore less exposed to frontal rainfall than the north-west of England (e.g. Burt and Horton, 2007) as well as much of the remainder of the country. Frontal rainfall, associated with westerly weather patterns (Wilby et al., 1997), is the predominant form of extreme precipitation in autumn and winter for the western U.K. (Rust et al., 2009), and increases in winter rainfall, as well as autumn rainfall and heavy rainfall have been predominantly observed in western, upland areas of the British Isles since the middle of the 20th century (e.g. Osborn et al., 2000; Alexander and Jones, 2001; Werritty, 2002; Fowler and Kilsby, 2002; Osborn and Hulme, 2002; Maraun et al., 2008). In upland regions of north-west England, increases in winter rainfalls have been linked to increases in westerly and south-westerly weather types (Ferranti et al., 2010). Such rainfall trends have direct implications for river flows, and increased runoff and high river flows have been observed in the west of the U.K. (Dixon et al., 2006; Hannaford and Marsh, 2006, 2008). To support this distribution of trends, the seasonal distribution of the heaviest 50 daily rainfalls between the north-west of England and the north-east (Table 4.5) shows that autumn records 29 of these heavy rainfalls in the north-west but only 18 in the north-east, and the seasons of autumn and winter record 38/50 heavy rain days in the north-west but only 22/50 in the north-east. Meanwhile the number of these 50 events occurring in summer increases from ten to 23 from the north-west to the north-east (Table 4.5). The second factor may be related to the fact that the upper Ryedale series is sourced from an upland area exclusively: summer convective storms (that cause upland floods) occur frequently across wider upland areas (McEwen and Werritty, 1988). Convectional events typically occur in summer, due to high insolation and temperatures (e.g. Hand et al., 2004).

	upper Ryedale	Durham	England and Wales	North West England[1]	North East England
Winter	3	2	8	9	4
Spring	12	9	6	2	5
Summer	24	19	10	10	23
Autumn	11	20	26	29	18

Table 4.5: The seasonal distribution of the 50 largest daily rainfall totals recorded at all rainfall series over their complete records. The three Met Office rainfall series are based on 1931-2009 period, upper Ryedale period 1916-2009, Durham 1901-2009. [1] – North West England and Wales regional series. Upper Ryedale rainfall series formed from data contained in the Met Office MIDAS database. England and Wales Precipitation Series downloaded from the Met Office Hadley Centre website. England and Wales Precipitation Series and regional series data: © Crown Copyright 2011, dataset reference: Alexander and Jones, 2001. Durham rainfall data provided by Professor Tim Burt.

	upper Ryedale (1916-2009)	Durham (1901-2009)	England and Wales (1931-2009)
Winter	17.6	13.6	22.3
Spring	14.2	16.8	9.3
Summer	35.8	38.4	21.6
Autumn	32.4	31.2	46.8

Table 4.6: The percentage of heavy rain days occurring in each season for each of the three rainfall series. Heavy rain days defined using the DR1 threshold. At Durham, this threshold was calculated for the 1916-2009 period of the record. Upper Ryedale rainfall series formed from data contained in the Met Office MIDAS database. England and Wales Precipitation Series downloaded from the Met Office Hadley Centre website. England and Wales Precipitation Series data: © Crown Copyright 2011, dataset reference: Alexander and Jones, 2001. Durham rainfall data provided by Professor Tim Burt.

Assessing the proportion of summer and autumn rainfall occurring on heavy rain days (as these are the two seasons across the three records when heavy rainfall predominantly occurs), it can be seen that the contribution of heavy rainfall to summer rainfall has clearly increased sharply at upper Ryedale and Durham since the 1990s (Figure 4.9), with a smaller increase observed for the England and Wales series. From the late 1960s to the 1990s, Durham and England and Wales saw a general decline in summer heavy rainfall which was more marked than at upper Ryedale (Figure 4.9): for the England and Wales series, the decline in the proportion of summer rainfall falling on heavy rain days is statistically significant (1961-2000 period, $p = 0.02$)*.The increase in summer heavy rainfall from the 1990s to 2000s at Durham and upper Ryedale appears to be more dramatic in the context of the summer heavy rainfall record than at England and Wales: the increase in the running average (after 1990) is larger than its earlier decline at upper Ryedale and Durham, but this is not the case in the England and Wales series (Figure 4.9). A comparison of the largest summer rainfalls recorded for the three series also supports this pattern: comparing the mean summer maximum falls for the five year periods 1991-1995 and 2001-2005, there are increases at upper Ryedale (20.7-50.4mm), Durham (20-34.4mm) and England and Wales (14.1-18.9mm). The increase in summer maxima from the early 1990s to 2005 is most pronounced at upper Ryedale, is clear at Durham and is least marked for England and Wales; a decline in mean highest rainfalls from the 2001-2005 to 2006-2009 period is evident in all three records, again most pronounced at upper Ryedale.

There is a further difference in the autumn heavy rainfall record (Figure 4.10) which shows a large amount of variation, but a lack of overall trend at Durham and upper Ryedale. However a steady increase in autumn heavy rainfall from the 1960s to the 2000s is observed at England and Wales, with the running mean reaching its highest level in the late 2000s (Figure 4.10). This increase is statistically significant at the 95% confidence level (p-value = 0.02, 1961-2009 values)*, in contrast with the Durham and upper Ryedale records which give p-values that are greater than 0.9 over this period.

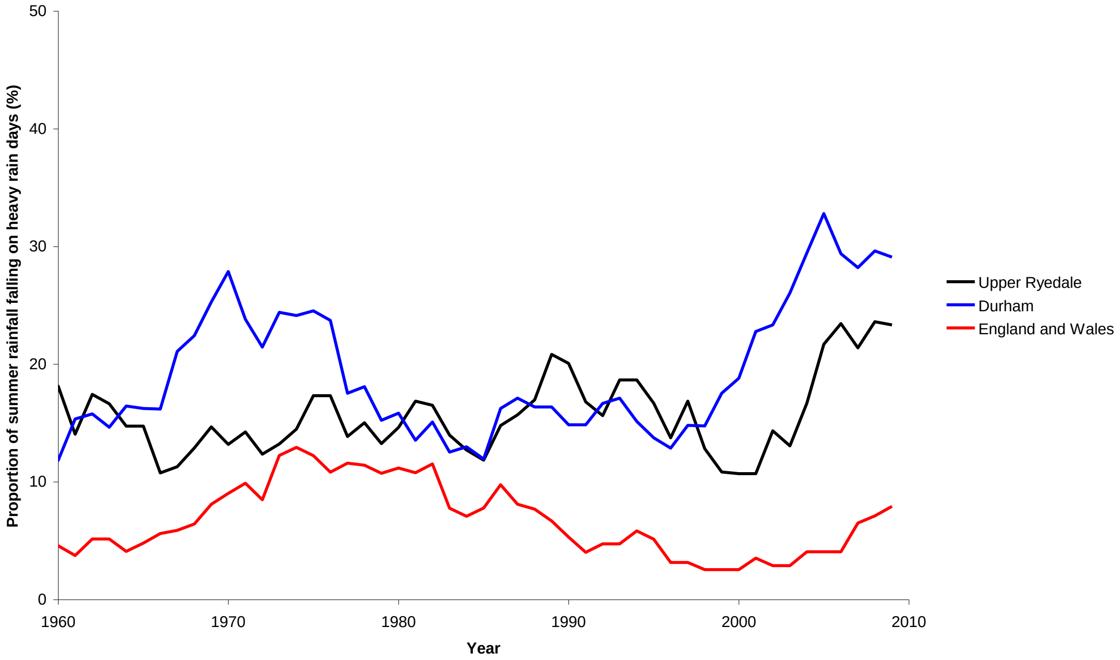


Figure 4.9: The proportion of summer rainfall falling on heavy rain days at upper Ryedale, Durham and England and Wales, showing ten year running means from 1960-2009. Upper Ryedale rainfall series formed from data contained in the Met Office MIDAS database. England and Wales Precipitation Series downloaded from the Met Office Hadley Centre website. England and Wales Precipitation Series data: © Crown Copyright 2011, dataset reference: Alexander and Jones, 2001. Durham rainfall data provided by Professor Tim Burt.

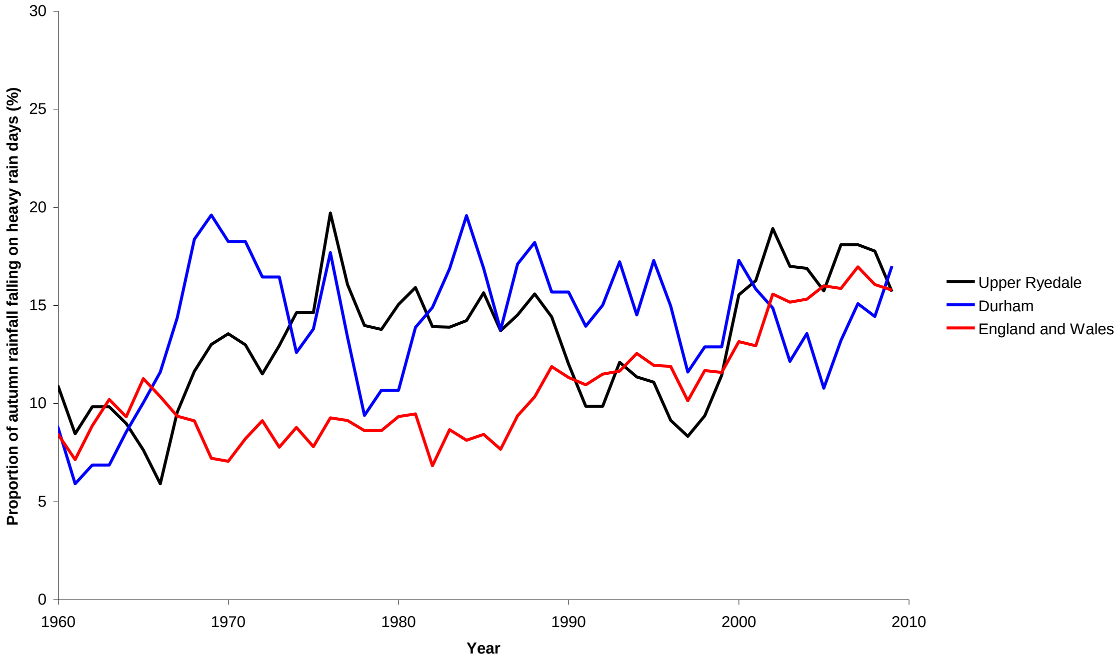


Figure 4.10: The proportion of autumn rainfall falling on heavy rain days at upper Ryedale, Durham and England and Wales, showing ten year running means from 1960-2009. Upper Ryedale rainfall series formed from data contained in the Met Office MIDAS database. England and Wales Precipitation Series downloaded from the Met Office Hadley Centre website. England and Wales Precipitation Series data: © Crown Copyright 2011, dataset reference: Alexander and Jones, 2001. Durham rainfall data provided by Professor Tim Burt.

The above trends suggest that while summer is an extremely important season for heavy rainfall events across the country, it is more important (in terms of the tendency for heavy rainfall to occur in summer, and in terms of a recent increase in summer heavy rainfall) in the north-east (as evidenced by the Durham and upper Ryedale series) than in the country as a whole, where heavy rainfall in autumn tends to be more frequent and has observed a steady increase from the middle of the 20th century. However, summer heavy rainfall remains an important driver of flash flood risks, given the documented tendency for most extreme rainfall events in the U.K. to occur in summer (e.g. Hand et al., 2004), as well as the incidence of upland flash flood events in summer (Section 1.2). Furthermore, strong (statistically significant) correlations exist in the winter:summer rainfall ratio between upper Ryedale and Durham (coefficient = 0.79)* and England and Wales (coefficient = 0.81)*. Winter rainfall totals increased relative to summer totals from the mid-20th century to the turn of the century, however since then this trend has reversed and ratios have sharply decreased, resulting from a period of wet summers (Figure 4.11).

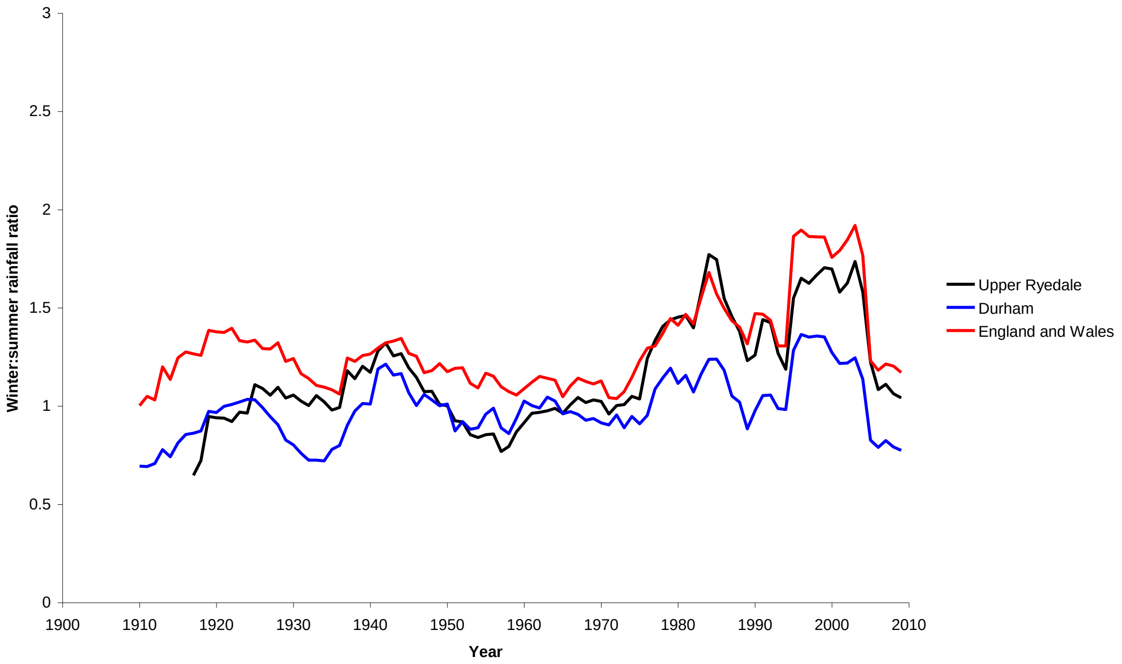


Figure 4.11: The winter:summer rainfall ratio at upper Ryedale, Durham and England and Wales, showing ten year running means. Upper Ryedale rainfall series formed from data contained in the Met Office MIDAS database. England and Wales Precipitation Series downloaded from the Met Office Hadley Centre website. England and Wales Precipitation Series data: © Crown Copyright 2011, dataset reference: Alexander and Jones, 2001. Durham rainfall data provided by Professor Tim Burt.

4.3 Private rainfall record analysis

Additionally, the privately kept rainfall records from Helmsley and Sproxton (Figure 3.2) prove useful in corroborating recent trends in rainfall established by the upper Ryedale series described above. The available data from Helmsley (1990-present, kept by Norman Railton) and Sproxton (1994-present, kept by Alan Agar) supports the increase in annual rainfall totals from the early to mid 1990s to the end of the 1990s and the 2000s, the latter period being relatively wet (Figure 4.12). There are very strong, statistically significant correlations between annual rainfall totals recorded in the upper Ryedale record and both private rainfall records (coefficients: Helmsley 0.88*, Sproxton 0.9*, p-values = 0.0 in both cases). Furthermore, monthly rainfall totals at the Helmsley record produce a correlation coefficient with the upper Ryedale series of 0.83* (n = 236); monthly totals at Sproxton also produce an extremely strong correlation with the official series (0.91*, n = 188). Both these relationships are highly statistically significant (p = 0.0 in both cases). Seasonal rainfall patterns appear consistent between the private rainfall records and the upper Ryedale series. The winter:summer rainfall ratios from the stations suggest particularly wet winters (relative to summers) in 1991 and 1995: in the latter year, the upper Ryedale series recorded the second-driest summer on record (on a normalised basis, 1916-2009) (Figure 4.13). Similarly, the records clearly identify consistently low ratios over the mid-to-late 2000s associated with a number of wet summers, with an increase in raw summer rainfall totals from the early 1990s to the end of the records. Despite the amateur nature of these private records, they correlate extremely strongly with the 'official' rainfall data.

The private rainfall record at Helmsley also contained information on the maximum daily rainfall total collected annually, and the annual total of days recording 16 mm of rainfall and above. A comparison with the maximum daily falls recorded annually in the upper Ryedale series gives a strong correlation coefficient of 0.78* (n = 19). A further correlation coefficient of 0.65* was found between heavy rain days at Helmsley (daily rainfall >16 mm) and the annual frequency of DR1 rain days in the upper Ryedale series (n = 19). Although these correlations are statistically highly significant (p = 0.0001, 0.0028 respectively), the correlations are slightly weaker than those for annual and monthly totals described above. Given the fact that localised heavy rainfall events are often not well recorded by rain gauges (Archer, 1992) (as was clearly documented in the experience of the 19th June 2005 rainfall event (Wass et al., 2008)), this slightly weaker relationship is to be expected.

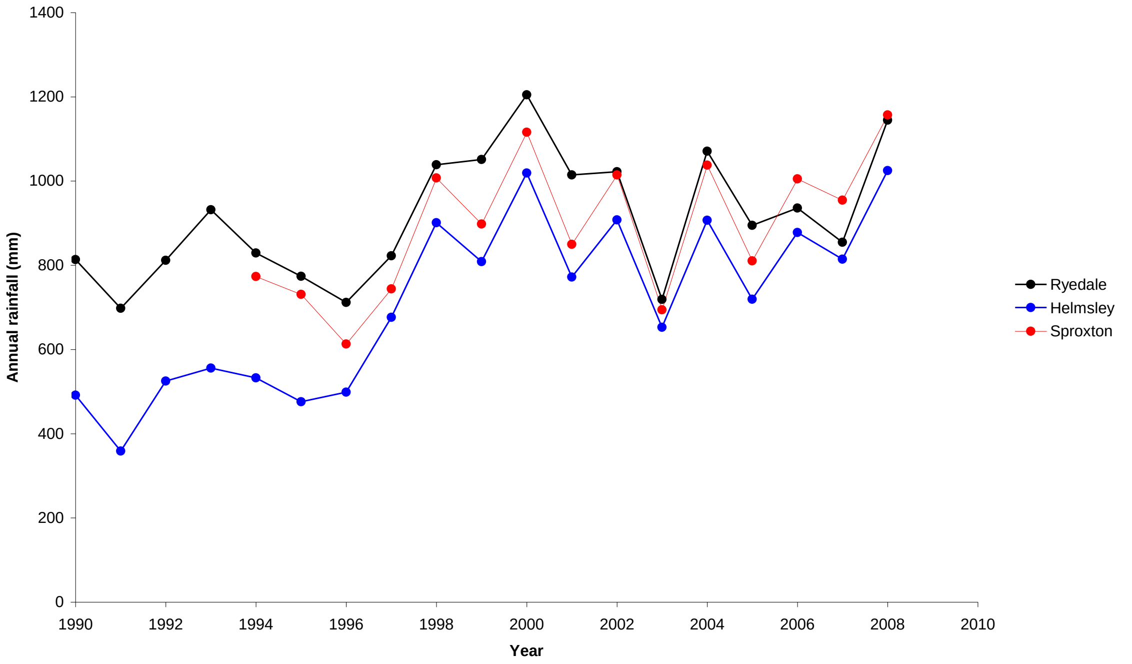


Figure 4.12: Annual rainfall totals recorded in the upper Ryedale series and in the private rainfall records from Helmsley and Sproxton. Upper Ryedale rainfall series formed from data contained in the Met Office MIDAS database. Private rainfall data provided by Norman Railton (Helmsley) and Alan Agar (Sproxton).

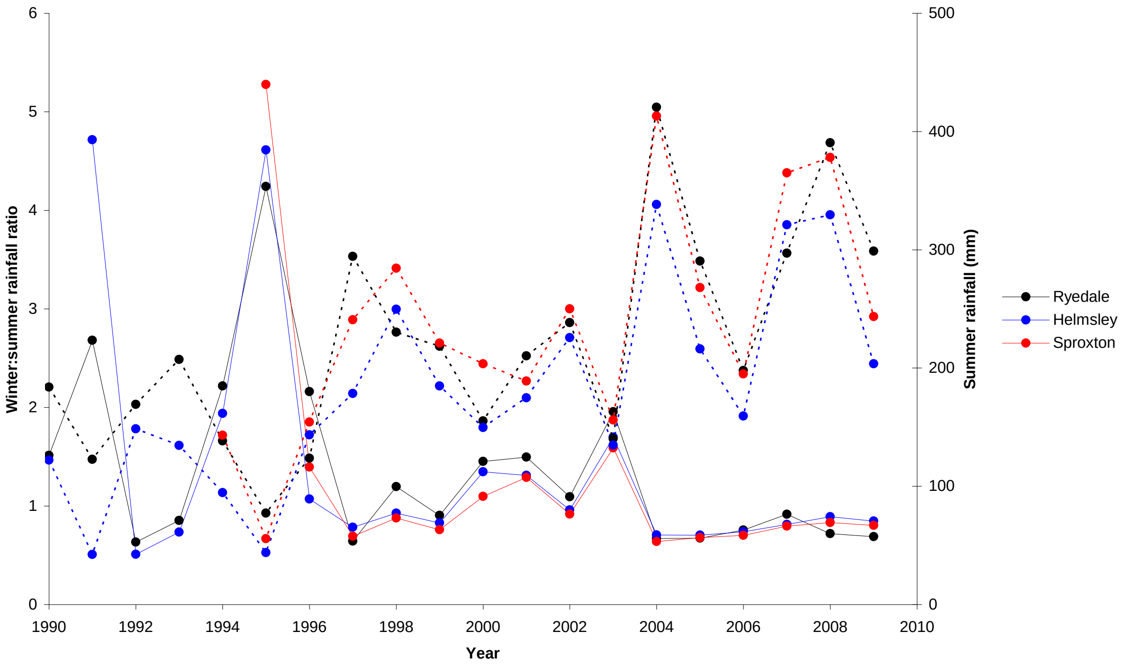


Figure 4.13: The winter:summer rainfall ratio (solid line) and summer rainfall totals (dashed line) recorded in the upper Ryedale series and in the Helmsley and Sproxton private records. Upper Ryedale rainfall series formed from data contained in the Met Office MIDAS database. Private rainfall data provided by Norman Railton (Helmsley) and Alan Agar (Sproxton).

4.4 Local perceptions of past rainfall in Helmsley

Questionnaire respondents were asked to indicate how wet or dry they remembered past decades to be, in terms of the amount of rain which fell. They were asked to provide information for all decades that they had lived in Ryedale, and any earlier decades that they could recall. A summary of the record is shown in Table 4.7 and Figure 4.14 below. There is a clear, rapid decline in the response rate for decades further back in time (Figure 4.14), which is statistically significant at the 95% level (2000s-1930s, p = 0.0002)*. Over three-quarters of questionnaire respondents could provide an opinion on the relative rainfall of the most recent period (the 2000s), and the response rate declines to 55% for the 1990s. This response rate decreases steadily with subsequent decades, and less than a quarter of all questionnaire respondents provided an estimate of rainfall in the 1960s and less than

10% responded when asked about the rainfall of the 1940s and 1930s (Table 4.7). It is unsurprising that the people who gave a response to the rainfall of decades which were increasingly further back in time tended to be of an increasing age (Figure 4.14). The mean age of respondents for the 2000s, 1990s, 1980s and 1970s does not differ greatly, with average ages between 59 and 63 years old. However, the average age of respondents for the 1950s, 1940s and 1930s is over 70 years old. Similarly, those respondents who could respond to the rainfall of earlier decades typically had lived in the area longer. As an example, those who provided information on mean rainfall in the 2000s had lived, on average, just over 26 years in the upper Ryedale area. This increases gradually to over 40 years by the 1970s and over 45 years in the 1950s, 1940s and 1930s. The increases in the age and residence time of respondents who recalled rainfall for decades further back in time are both statistically significant at the 95% level (p = 0.0029*, 0.0001* respectively).

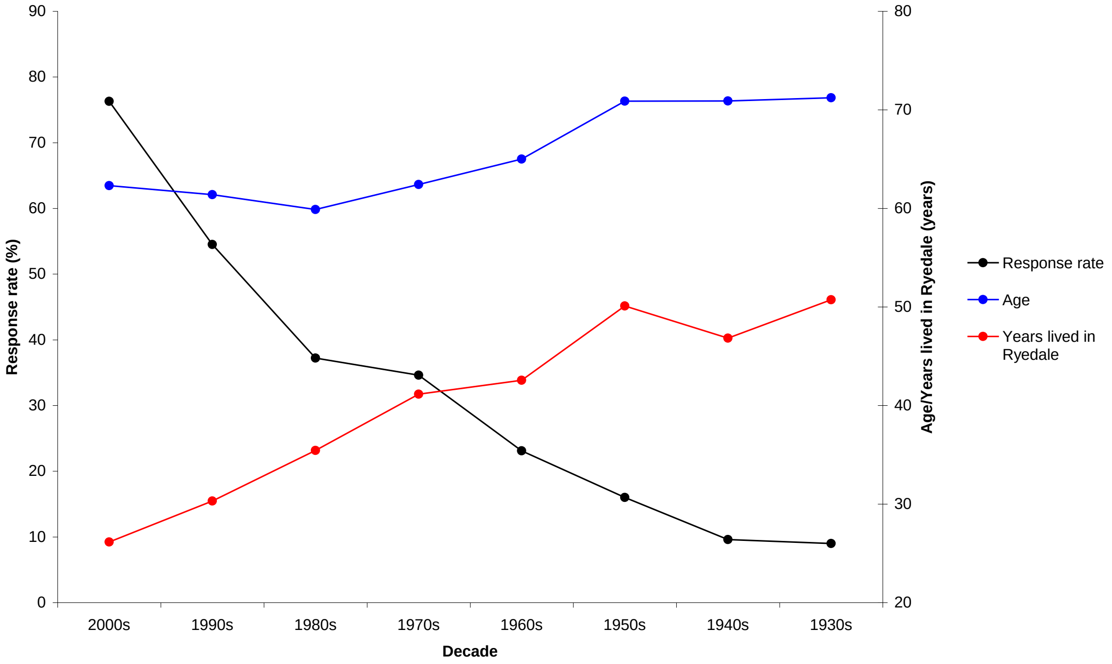


Figure 4.14: Changes in the response rate, mean age and mean residence time of questionnaire respondents in Helmsley, for those respondents who recalled information about rainfall in each decade. Response rate is expressed as a percentage of all questionnaire responses (n =156).

Decade	Drier than average (%)	About average (%)	Wetter than average (%)	n	Response rate (%)
2000s	6.7	26.1	67.2	119	76.3
1990s	14.1	63.5	22.4	85	54.5
1980s	15.5	82.8	1.7	58	37.2
1970s	61.1	38.9	0	54	34.6
1960s	38.9	55.6	5.6	36	23.1
1950s	24	48	28	25	16
1940s	26.7	73.3	0	15	9.6
1930s	21.4	71.4	7.1	14	9

Table 4.7: The perceived wetness of past decades in upper Ryedale according to questionnaire responses. The response rate is the number of questionnaire respondents providing an answer on the decade in question (n), as a percentage of the overall number of questionnaires (156).

Figure 4.15 summarises the proportions of respondents who believed that each decade was drier than average, wetter than average or had about average rainfall, compared with the decadal means of normalised rainfall totals from the upper Ryedale rainfall series (Table 4.1). The most recent (incomplete) decade, the 2000s, was perceived by over two-thirds of respondents to be wetter than average. Meanwhile, six out of ten people who responded about the 1970s thought that that decade was drier than average, the highest proportion of any decade. In the upper Ryedale rainfall series, the 2000s are the wettest period (although not yet a complete decade) in the full 1916-2009 annual series, with the 1970s the second driest complete decade in the series (not including the five year 1916-1920 period). The proportion of questionnaire respondents who felt that the 1960s were drier than average, 39%, is the second-highest proportion of any decade in the questionnaire responses (Table 4.7). However, the increase in annual rainfall totals from the 1960s onwards (Section 4.1.1) appears to be reflected in the questionnaire responses, as from the 1970s to the 2000s the percentage of respondents stating decadal rainfall was drier than average declines dramatically (61.1% to 6.7% over the four decades) while those who say that a decade was wetter than average increases sharply (0% to 67.2%) (Figure 4.15). In the upper Ryedale rainfall series, the 1930s are the second-wettest decade on record (Section 4.1.1, Table 4.1); however, the decade was not perceived as particularly wet by questionnaire respondents (Table 4.7). The fact that the 1930s occurred nearly 70 years ago, and the associated low number of respondents (14 in total) are likely to reduce the clarity of perceptions. Overall there is a strong, statistically significant correlation (coefficient = 0.77)* between the actual normalised, mean annual rainfall totals in the 1930s to the 2000s, and the perceived wetness of these decades (defined as the percentage of respondents who thought the decade was 'wetter than average' minus the percentage who regarded a decade as 'drier than average'). By contrast, the correlation between perceived wetness and the proportion of decadal rainfall falling as heavy rainfall is extremely weak (coefficient = 0.07).

Throughout the record there is a tendency for a large proportion of respondents to respond that a decade had 'About average' rainfall. The only two decades where 'About average' does not have a majority or a plurality of responses are the 2000s (where the majority state that the decade was wetter than average) and the 1970s (where most view the decade as drier than average). In the 1980s, over eight out of ten respondents viewed the rainfall as about average, the highest proportion of any decade (Table 4.7). Indeed, over the period 1916-2009, mean normalised rainfalls in the 1980s were close to average (0.8% above mean rainfall). Also, 63.5% of respondents in the 1990s viewed that decade as having about average rainfall: rainfall totals for this decade were also extremely close to average, with a mean normalised annual total of 99.8%. In the 1930s and 1940s, over 70% of respondents stated that rainfall was about average. However, in the 1930s actual rainfall totals were well above average (nearly 6% above the mean) and in the 1940s totals were 1.5% below mean annual rainfall. Again, the large amount of time that has passed since these decades and the low number of respondents for these decades are likely to be the causes of this disparity. The accuracy of recollections of climate has been found to reduce for times further back in the past (Malmberg and Blanken, 2006).

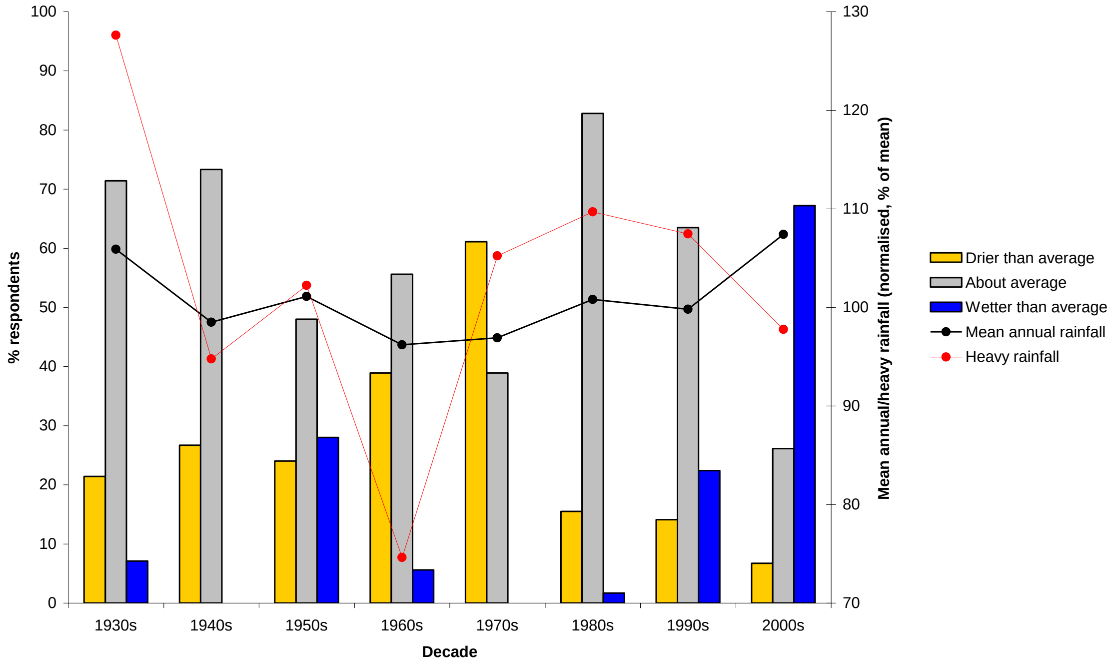


Figure 4.15: The perceived wetness of past decades in upper Ryedale according to questionnaire responses, also showing the mean normalised rainfall total, and normalised proportion of annual rainfall falling on heavy rain days, in the respective decades from the upper Ryedale rainfall series. Note that the 2000s are an incomplete decade (2001-2009). Upper Ryedale rainfall series formed from data contained in the Met Office MIDAS database.

Perceived changes in seasonal rainfall in Ryedale are shown in Table 4.8. It can be seen that in all seasons, the proportion of individuals believing that the season had got wetter is greater than the proportion stating that the season had got drier; therefore, the dominant perception is that all seasons have got wetter. However in two seasons (spring and autumn), a plurality and a majority (respectively) of respondents stated that they believed that rainfall had not noticeably changed, suggesting that trends in these particular seasons are much weaker. For the other two seasons, the responses to winter rainfall are very evenly distributed, with the percentage of respondents believing winters to have got wetter over the time that they had lived in Ryedale (35%) being only slightly above the percentages who believed that rainfall had not changed (33.6%) and who thought winters had got drier (31.4%) (Table 4.8). Meanwhile, two-thirds of respondents believed that summers have got wetter, with only 4.5% stating that they had got drier: the strongest positive signal in any season.

Season	Have got drier (%)	No change (%)	Have got wetter (%)	n	Response rate (%)
Winter	31.4	33.6	35	137	87.8
Spring	17.2	44	38.8	134	85.9
Summer	4.5	29.1	66.4	134	85.9
Autumn	12.7	62.7	24.6	134	85.9

Table 4.8: The perceived changes in seasonal rainfall in upper Ryedale according to questionnaire responses. Respondents were asked to estimate the trend for the years that they had lived in upper Ryedale. The response rate is the number of questionnaire respondents providing an answer on the decade in question (n), as a percentage of the overall number of questionnaires (156).

Respondents were also asked their views on whether three types of precipitation (snowfall, prolonged rainfall, and intense, heavy thunderstorms) occured more or less often than they used to. Clearly, respondents perceived overwhelmingly (93.6%) that snowfall was occurring less often (Table 4.9). With regard to the two categories discussing heavy rainfall, a plurality of respondents (46%) perceived an increase in the frequency of prolonged rainfall while 41% suggest no change. The most frequent response for intense, heavy thunderstorms was, by contrast, 'no change' (43.5%) although just over four out of ten respondents (40.6%) suggested such storms were occurring more often. Clearly the dominant perception was that heavy rainfall was occurring more frequently in the Ryedale area. There is a statistically significant association between respondent age and respondents' perceptions of rainfall in the 2000s period ($\chi^2 = 7.15$, $p = 0.028$, $n = 80$)* as respondents who believed that the 2000s were wetter than average (mean age = 59.3 years old) were more likely to be younger than those who believed the decade was drier than average (mean age = 68.5 years old), or had about average rainfall (mean age: 69.6 years old). On a decadal basis, the proportion of respondents rating the 2000s as 'Wetter than average' increases steadily, from 50% of those born in the 1910s and 1920s to 100% by the 1970s and 1980s, with a moderate increase in the decades in between (Figure 4.16). The vast majority (84.8%) of those residents born in the 1950s and later (n = 33) believed that the 2000s decade was 'Wetter than average'; however, for those respondents born before the 1950s (n = 47), the proportion who believe that the 2000s were wetter than average is much lower at 59.6%. The reason for this difference in perceptions between older and younger residents may be due to the nature of the precipitation record of upper Ryedale, which saw a very dry decade in the 1960s and a subsequent increase in annual rainfall totals (Table 4.1) and heavy rainfall frequency (Figure 4.6) to the 2000s. Therefore, younger residents are more likely to view the 2000s as a very wet decade, given the experience of the local climate that they have had. Meanwhile, older residents are possibly more likely to recall decades prior to the 1960s which saw higher amounts of rainfall, including the 1950s and in particular the 1930s. Similarly, there are two further statistically significant associations between respondent age and perceptions of rainfall change: perceived change to summer rainfall ($\chi^2 = 6.607$, $p = 0.037$, $n = 92$)* and perceived change to the frequency of intense, heavy thunderstorms ($\chi^2 = 7.239$, $p = 0.027$, $n = 94$)*. Respondents who perceived that summers had got wetter were more likely to be younger than those who believed that they had got drier, and respondents who believed that intense, heavy thunderstorms were occurring more often were also more likely to be younger than those who perceived that they were occurring less often.

Precipitation type	Occurring less often (%)	No change (%)	Occurring more often (%)	n	Response rate (%)
Snowfall	93.6	5.0	1.4	140	89.7
Prolonged rainfall	12.9	41.0	46.0	139	89.1
Intense, heavy thunderstorms	15.9	43.5	40.6	138	88.5

Table 4.9: The perceived change to heavy rainfall frequency in upper Ryedale according to questionnaire responses. 'Prolonged rainfall' was defined as rainfall events lasting over a day. The response rate is the number of questionnaire respondents providing an answer on the decade in question (n), as a percentage of the overall number of questionnaires (156).

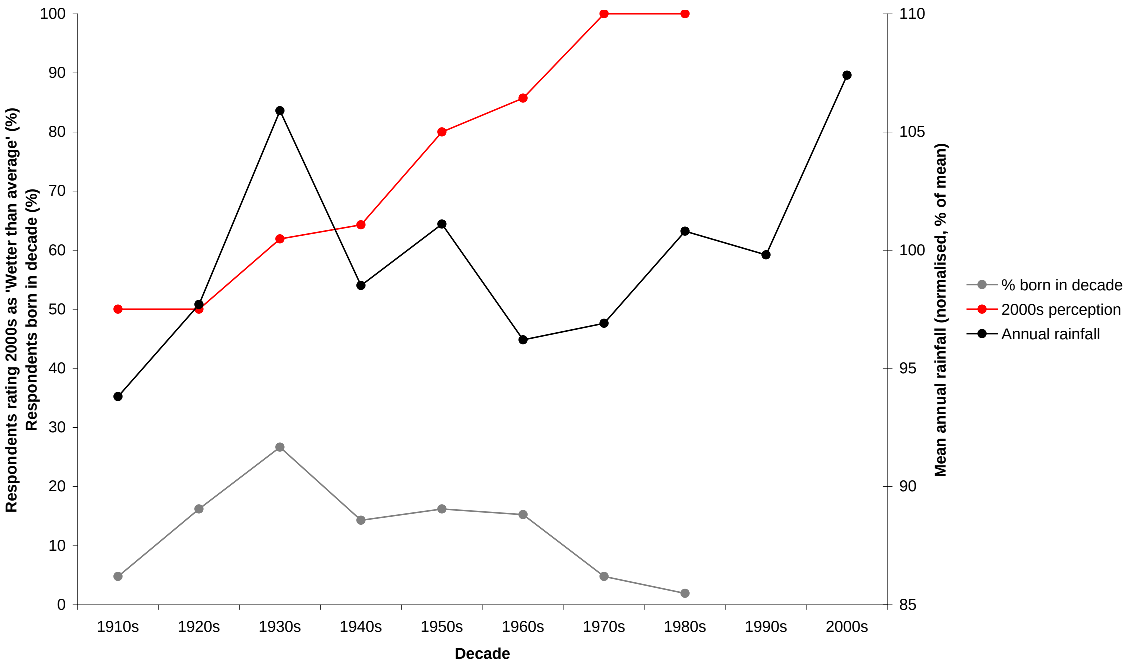


Figure 4.16: Comparison of the percentage of questionnaire respondents born in each decade who thought that the 2000s period was 'wetter than average' and the mean normalised annual rainfall totals for each decade/period, also showing the percentage of respondents born in each decade. For perception of the 2000s, n = 80 and for percentage of respondents from each decade, n = 105. Note that 1910s (1916-1920) and 2000s are not complete decades in the rainfall series. Annual rainfall data derived from the upper Ryedale rainfall series, which was formed from data contained in the Met Office MIDAS database.

A comparison of the periods of time when responders were born with their perceptions of changes to summer rainfall, and thunderstorm frequency, along with the actual rainfall statistics shows, firstly, that younger residents are more likely to perceive an increase in summer rainfall totals as well as heavy thunderstorms (Figures 4.17, 4.18). Secondly, as with the perception of the wetness of the 2000s decade described above, there is a correlation with rainfall data. Although summer rainfall totals have generally declined since the 1960s, there has been a marked increase in summer rainfall totals from the 1990s to the 2000s (Figure 4.2). Therefore, younger residents (especially those born after the 1950s) are more likely than residents born in the first half of the 20th century to perceive this increase in summer rainfall, shown by an increase in the 'perception' graph over this time period on Figure 4.17. Older residents have experience of a longer record. Similarities to such perceptions have been found in analyses of perceived changes to seasonal climate: the perception that U.K. winters are getting warmer may result from older residents' experience of severe winters (e.g. 1946-7, 1962-3) or younger residents' experience of mild winters in the 1990s and 2000s (Hulme et al., 2009). Similarly, the tendency for questionnaire respondents who perceive that thunderstorms are occurring more frequently to be younger than those who believe that they are occurring less often may possibly link to the record of heavy rainfall, which shows an increase in the frequency of heavy rainfall events since the 1960s (Figure 4.6), with additionally extremely large daily rainfalls recorded since the late 1990s. Residents, in particular those born in the 1920s and 1930s, could have experience of these decades which saw an extremely high frequency of heavy rainfall, and therefore be less likely to perceive an increase in thunderstorms or heavy rainfall generally over this longer-term record: this is suggested by the low perception of an increase in thunderstorms in decades from respondents born in the early 20th century (Figure 4.18). Younger residents are more likely to perceive an increase in the frequency of thunderstorms due to their relatively shorter lifespan. Perceptions of changes to the 'wetness' of climate, whether assessed by decade, season or type of rainfall, reflect the fact that individual constructions of climate (based upon memories, experiences and knowledge) are formed in a different way to statistical analyses (Hulme et al., 2009), and lay expectations of climate, based upon experience, have been found to differ from climatological records (Rebetez, 1996).

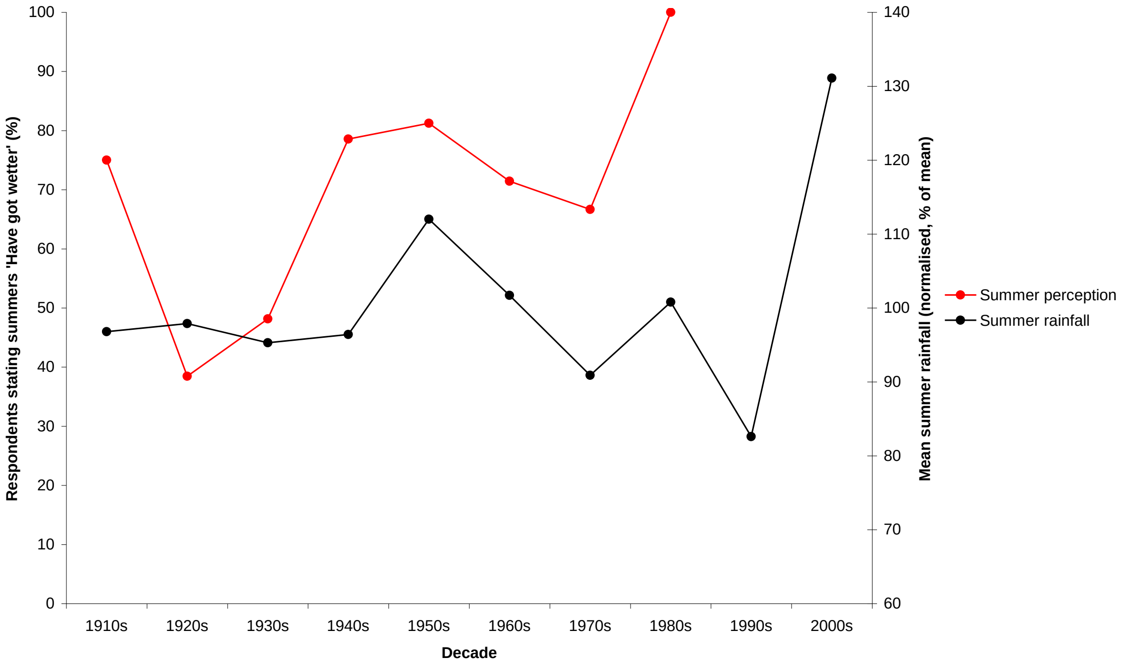


Figure 4.17: Comparison of the percentage of questionnaire respondents born in each decade who thought that summers 'have got wetter' over the time that they have lived in Ryedale, and the mean normalised summer rainfall totals for each decade/period. For perception of summer rainfall, n = 92. The 1910s and 2000s are not complete decades. Summer rainfall data derived from the upper Ryedale rainfall series, which was formed from data contained in the Met Office MIDAS database.

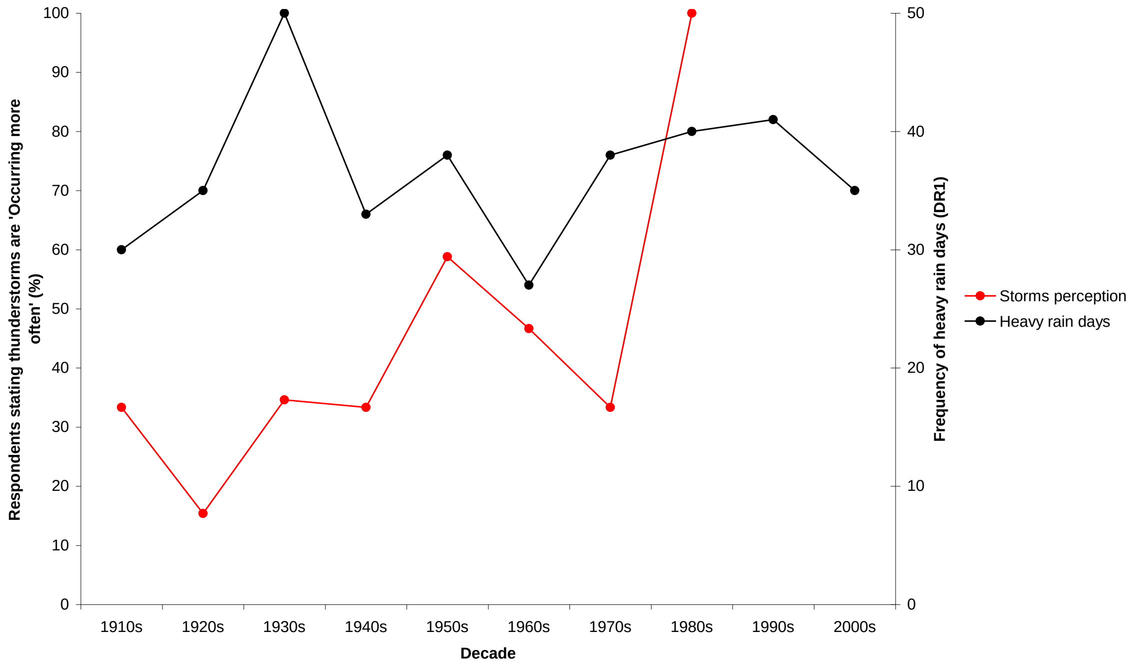


Figure 4.18: Comparison of the percentage of questionnaire respondents born in each decade who thought that thunderstorms are 'occurring more often' over the time they have lived in Ryedale, and the decadal frequency of heavy rain days (DR1 threshold). Figures for the 1910s and 2000s are estimated as if the periods were complete decades, based on existing data. For respondents, n = 94. Heavy rainfall data derived from the upper Ryedale rainfall series, which was formed from data contained in the Met Office MIDAS database.

Furthermore to the questionnaire data described above, in interviews in upper Ryedale many interviewees provided their opinions on changing patterns of rainfall in the region. One of the dominant views was that rainfall was becoming recently more extreme in the area, with a tendency to more heavy falls of rain in summer. For example, two residents interviewed offered both of these views:

Over the time you've lived here, do you think that floods in this area are occurring more frequently, or do you think they're getting more serious?

Male: I think heavy downpours are occurring more frequently.

Why would you say that is?

Male: I don't know why, but we seem to be having big flash downpours. They seem to be more frequent. We seem to have more wet days of heavy rain. This summer, I think there has hardly been a day when we haven't got soaking wet.

Female: Through the summer.

Male: I've even started taking a spare set of clothes with me. I've not done that before. Regularly on a Tuesday we get wet.

Female: Soaking wet.

Male: There just seems to be more rain. I don't know whether it's total rainfall or just downpours.

Another interviewee also spoke of an increase in the frequency of intense storms in general, across the country. He also pointed out the need to look at a long record, to assess whether 'freak' storms had been recorded in the past:

...I know we're getting (inaudible) adverse weather, we're having flash storms and this sort of thing, like, there were in the South...

...

...And the thing is now we seem to be getting more and more localised storms, erm, and flooding and things like this really.

You would say that the flood risk in this area is increasing, do you think?

I would say yeah, slightly. Only slightly, there probably is a bigger risk now. Probably because of the climate, climate change, erm, because of these freak storms. Unless the storms in the past have been recorded, erm, like some were years and years gone by, unless really freak storms are recorded, we don't really have the knowledge to say that the storms did happen then...

Some argued that the summer season tended to have a high risk of flooding due to the dry ground leading to rapid runoff:

Do you think it is likely that the area will experience more big floods in the future?

Well if we have these heavy concentrated rainstorms it's always possible. Particularly if it happens over the summer, where the water washes straight off the surface and into the river courses. It could happen, but I think it will very much depend on where the rain is, it could be a bit of a Boscastle situation, which is what we got last time?

Other residents showed awareness of links between the increase in (summer) heavy rainfall and increasing flood risks. Other examples of flash floods caused by intense summer rainfall were provided by some interviewees:

...I mean, Boscastle down in the south was one instance where it was… the storm was just in that given area, and that's what did the damage, I think back in Howarth where I came from, a long time ago in the Bronte period, there was a big storm there and erm… the bogs on the moor couldn't take any more water and so it just gave way and the whole valley the tops of the moors… it just got all swept away down the valley. And I think this is what's happening now, heavy storms that are localised, and I think that's what causes all these big flash floods because usually they're localised storms, and the same down in the south, heavy rain in given areas, big storms, with a lot of water.

...One (problem) is we're getting heavy downpours of rainfall, particularly in the summer.

Is this in this area?

I get the feeling it's all over. The flood they had in Devon a couple of years ago, Hull, Sheffield, Gloucester last year, that was just heavy precipitation in the summer.

4.5 Discussion and chapter summary

Based upon rainfall records alone, it is clear that heavy rainfall events in upper Ryedale have fluctuated over time in terms of their frequency, magnitude and contribution to overall rainfall. The dominant pattern throughout the 1916-2009 record has been one of 'wet' periods (with high annual rainfall totals, greater numbers of heavy rainfall events, and a large proportion of rainfall falling as heavy rainfall) and intervening drier periods. The alternation of wet and dry periods supports the arguments made by Lane (2008), who suggests that the late 1990s to 2000s constituted a flood rich period, which followed a flood poor period from 1960; similarly, Robson et al. (1998) used long flood records to place changes in flooding after 1960 into a fuller context which included the early 20th century. Increases in annual rainfall totals and heavy rainfall have been found in a number of U.K. studies (Osborn et al., 2000; Osborn and Hulme, 2002; Fowler and Kilsby, 2003; Maraun et al., 2008). In this study, from the 1960s to 2009, heavy rainfall, annual maximum rainfalls and annual rainfall totals have broadly increased. However, they need to be placed in a context which recognises the low amount of rainfall (and low frequency of heavy rainfall) which fell in the 1960s, and the very wet nature of decades prior to the 1960s, in particular the 1930s. Long-term environmental monitoring is a valuable method for placing recent observations in a fuller context (Robson et al., 1998); additionally, rare events are most likely to be ‘captured’ by long-term monitoring than in shorter-term studies (Burt, 1994). The use of a composite, 94 year time series overcomes the short-term term nature of rainfall records in the U.K. (Lane, 2008) and also the sparse monitoring network in upland areas (Macklin and Rumsby, 2007).

The dominant trend in seasonal rainfall totals has been a general increase in the wetness of winters relative to summers since the 1960s, with an additional increase in heavy rainfall in winter. Summer rainfall totals have generally declined from the 1960s, with little change to summer heavy rainfall frequencies over this period. These trends are in line with those found from U.K. studies (Osborn et al., 2000; Osborn and Hulme, 2002; Fowler and Kilsby, 2003; Jenkins et al., 2008; Maraun et al., 2008) as well as rainfall studies from northern England (Fowler and Kilsby, 2002; Lane, 2003; Barker et al., 2004; Orr and Carling, 2006; Burt and Horton, 2007; Malby et al., 2007; Burt and Ferranti, 2012). However, in the most recent decade, this trend has reversed with a sharp increase in summer rainfall totals and in heavy rain days in summer. Winters since 2001 have recorded an extremely low number of heavy rainfall events, and the lowest ever contribution of heavy rainfall to seasonal rainfall; summers meanwhile have observed a very high number of heavy rain days, including a sharp increase in the proportion of summer rainfall falling on heavy rain days. Additionally there has been a collection of very heavy daily rainfall totals recorded in summers over the last ten-to-15 years. The maximum daily rainfall recorded in summer has sharply increased since the late 1990s as a result. This increase in heavy summer rainfall is symptomatic of the recent experience of summer flooding in the U.K., with widespread flooding in England and Wales during summer 2007 (Marsh and Hannaford, 2007) and major flash flood events in Boscastle, Cornwall (summer 2004) (Burt, 2005) and Alston, Cumbria (summer 2007) (Cumberland and Westmorland Herald, 2007) as well as the upper Ryedale flash flood in 2005. Given trends in seasonal precipitation over the latter half of the 20th century (e.g. Osborn and Hulme, 2002; Maraun et al., 2008), as well as projections of future climate, which suggest increases in heavy rainfall in winter across the U.K. (Fowler and Ekström, 2009) as well as wetter winters more generally (Murphy et al., 2009), these flood events and heavy summer rainfalls appear to be unusual (Marsh and Hannaford, 2007; Lane, 2008). A comparison of the upper Ryedale series with other records suggests that heavy rainfall in England and Wales is more likely to occur in autumn than in summer, and suggests that heavy rainfall in summer has increased less for England and Wales than at upper Ryedale and other areas in the north-east of England. This results from the reduced exposure of north-east England to moist, westerly winds and frontal rainfall, which is the dominant mechanism of extreme rainfall in the western U.K. (Rust et al., 2009); similarly, in western areas, autumn and winter are the seasons where the largest number of heavy rainfall events occur, rather than summer. The tendency for western parts of regions to experience wetter winters has been found in Yorkshire (Fowler and Kilsby, 2002) and Scotland (Werritty, 2002) and are likely linked to increasing westerly weather patterns in winter, related to the North Atlantic Oscillation (Wilby et al., 1997). Most of the positive, statistically significant trends in the magnitude and frequency of flooding and high river flows have been found in upland, western catchments in the north and west of the U.K. since the 1960s (Hannaford and Marsh, 2008). Regionally-based rainfall studies in northern England and Cumbria found that heavy rainfall increases in winter during the late 20th century are greatest at high altitudes (Malby et al., 2007; Burt and Ferranti, 2012).

In the long-term monitoring record, heavy rainfall in summer is less unusual. Over the whole 94 year record, the highest daily rainfall totals have tended to occur in the summer months, and summer has recorded a higher amount of heavy rain days than any of the other seasons. Similarly, although recent summer heavy rainfalls are unusual for the Ryedale record since the 1960s, prior to that decade similar high numbers of summer heavy rain days, and very heavy individual summer rainfalls have been experienced. The tendency for extreme rainfall to occur most frequently in summer has been noted in several studies (Collier et al., 2002; Hand et al., 2004; Rodda et al., 2009), and the majority of the largest daily rainfall totals (threshold: 200mm) recorded in the British Isles have occurred in summer (Burt, 2005). Furthermore, several upland flash floods in the north of England have occurred in summer (Carling, 1986; Harvey, 1986; Acreman, 1989; Cumberland and Westmorland Herald, 2007). Although some increases in winter rainfall have taken place since the 1960s, winter rainfall events tend to be less extreme at upper Ryedale than events in summer. Despite increases in the number of winter heavy rain days, they are less likely to contribute to flood risk than heavy rainfall in summer. The risk of heavy rainfall, and therefore flash flooding, in upper Ryedale is greatest in the summer months throughout the whole length of the record. Therefore, a period of wet summers with increased summer heavy rainfall, as has occurred after the year 2000, suggests a trend to an increased risk of flash flooding, as flash floods are associated with extreme rainfall and predominantly occur in summer (Merz and Blöschl, 2003). European climate modelling has also suggested that, although summer rainfall totals are projected to decline across Europe in the future, the most extreme rainfall events in summer may increase in intensity (Christensen and Christensen, 2003; Pal et al., 2004; Beniston, 2009), and predictions for the U.K. suggest that heavy rainfall in summer will make a greater contribution to seasonal rainfall (Kendon and Clark, 2008). A warmer climate could lead to a much more intense hydrological cycle and thus more frequent heavy rainfall (Frei et al., 1998). However, future changes to summer heavy rainfall are uncertain: Fowler and Ekström (2009) found that extreme precipitation in the U.K. will increase in winter, spring and autumn to 2100; with summer extreme precipitation set to have little change, although it was noted that regional climate models could not assess localised convective processes and heavy summer rainfall (Fowler and Ekström, 2009). Similarly, a study in central Europe (the Czech Republic) found increases in heavy summer (and winter) precipitation to the late 21st century, although with less agreement between models in summer (Kyselý and Beranová, 2009). Uncertainty in predicting changes to flood risks results from "...a spatial and temporal scale mismatch between coarse-resolution climate models and the smaller-grid scale of a drainage basin (Kundzewicz et al., 2010: 649). Therefore, assessing the future risk of flash floods in summer is very difficult based upon current modelling capabilities (Fowler and Wilby, 2010).

To summarise, the 19th June 2005 rainfall event is clearly an unusual event in terms of its intensity (the volume of rain falling in a short period of time) but is less unusual in terms of its daily volume, only constituting the fifth heaviest daily total in the 1916-2009 record. It is associated with a wet period from the late 1990s to present, and a period of wet summers. There is a long-term tendency for the heaviest rainfall events to occur in summer in the upper Ryedale record. An analysis of the England and Wales rainfall series suggests that autumn is the more important season for heavy rainfall occurrence, predominantly as the result of westerly rainfall patterns and frontal rainfall (Rust et al., 2009). These mechanisms of rainfall do not affect eastern areas such as upper Ryedale as much as the western U.K. Therefore, the 19th June 2005 rainfall was an extremely intense rainfall event, but the mechanism of rainfall and its timing were typical for the region as a whole.

Following the main analysis of long-term trends in heavy rainfall, a study of the perceptions of local climate among questionnaire respondents showed that perceptions of the changes to past rainfall, and seasonal and heavy rainfall, approximate the rainfall trends. Perceptions of decadal wetness suffer from a rapidly declining response rate, and views on rainfall prior to the 1960s do not seem reliable due to the low number of individuals responding. However, questionnaire respondents identified the dryness of the 1960s and 1970s, and the general increase in rainfall to the most present decade. Since the 1970s, the percentage of questionnaire respondents stating that decades were wetter than average has sharply increased, while the percentage of respondents viewing decadal rainfall as drier an average has declined at a similar rate. This pattern appears to be associated with the statistically significant rise in annual rainfall totals since 1961. Similarly, perceptions of seasonal rainfall are close to those shown by the rainfall record, as a large majority of respondents held the view that summers have got wetter while they had lived in upper Ryedale; it is possible that the wet summers observed in the 2000s period, with frequent heavy rainfall, have influenced this view. Respondents' views on rainfall changes in other seasons are more poorly defined, suggesting a perception of weaker (or no) trends in winter, spring and autumn over questionnaire respondents' lifetimes. Finally, heavy rainfall (in terms of prolonged rainfall and intense, heavy thunderstorms) is viewed by most as something which has increased in frequency. Aside from these general views, statistically significant associations between questionnaire respondent age and rainfall perceptions have been found to exist. Respondents who believe that rainfall in the 2000s period is wetter than average, view summers as having got wetter, and perceive an increase in the frequency of heavy thunderstorms are more likely to be younger than those with other perceptions of changes to rainfall. This suggests a link with the timing of recent rainfall trends, as increases in summer rainfall and the magnitude of heavy rainfall events have occurred very recently (in the last ten to 15 years) and so it is possible that residents with a shorter experience of Ryedale rainfall would be more likely to perceive these as the dominant rainfall trends. Older residents have a potentially longer memory and greater experience of the local climate, and are possibly less likely to perceive recent, short-term trends in rainfall as a result, and less likely to view recent changes in rainfall characteristics as exceptional or dominant. Similarly, older residents are more likely to be aware of longer-term increases in winter rainfall totals (relative to summer rainfall) since the 1960s and also heavy rainfall events that have occurred in earlier decades. Finally, privately collected rainfall records correlate strongly with the upper Ryedale rainfall series. Although relatively short (the longest record beginning in 1990), the private rainfall records have proved a useful indicator of recent trends in rainfall, including the increase in summer rainfall totals and a transition from a period of low-to-moderate rainfall to a number of particularly wet years after 2000. In upper Ryedale, where the official rainfall monitoring network is sparse (Section 3.7.1), the use of information derived from local communities has been found to be extremely useful in the assessment of recent climatic trends and in supporting the findings of a statistical analysis of a long-term precipitation series. Such locally sourced information has been assimilated in a number of forms, including numerical data (from private rainfall records), semi-quantitative data (derived from surveys) and verbal, qualitative data (from interviews). Local residents had a number of relevant, detailed insights into changes to local climate and flood risks. While many local residents were aware of an increase in heavy rainfall, particularly heavy thunderstorms in summer, some residents linked this to an increasing local flood risk. Some pointed out other flash floods (locally, nationally or from their own experience) which had occurred as a result of intense rainfall. Others mentioned that summer was often the season which had the highest flood risk. Residents' awareness of changes to local climate, and potential links to flash flood risk perception, are important areas of study, and a further analysis of residents' views of factors influencing local flood risks takes place in the following chapter.

Chapter 5

Assessment of residents' responses to flash flooding and local flood knowledge

This chapter describes the responses of the population of Helmsley, and villages in upper Ryedale, to a major flash flood event, based upon a series of in-depth interviews with individuals who were directly affected by flooding, and the results of a questionnaire sent to assess responses to flooding, risk perceptions and flood knowledge of the population of Helmsley as a whole. The chapter is made up of six main sections (Table 5.1) which describe firstly the experience of flash flooding in 2005, and then the ways in which two groups of residents (firstly, the population of an upland town, Helmsley, as a whole; and secondly, residents directly affected by flash flooding) have responded to the flash flood event in 2005. Following on from a discussion of past flooding in the previous section, there is a further self-contained analysis of possible past overbank floods as revealed through an analysis of relationships between high discharge events and rainfall. Perceived contributing factors to local flooding are then described, and the chapter finally concludes with a summary.

The data collection for this chapter utilised two main methods (described within Section 3.8). Firstly, the population of Helmsley as a whole was assessed by a questionnaire (total responses = 156). Secondly, individuals and households who were directly affected by flooding in 2005 were analysed during in-depth interviews. In total, twelve directly affected residents from nine different households were interviewed; of which ten people living in seven households were interviewed in Helmsley (Figure 5.1) and two people from two households were interviewed in the settlements of Rievaulx and Hawnby, situated at a higher altitude in upper Ryedale (Figure 5.1). The interviews undertaken in Helmsley took place in Ryegate, Sawmill Lane and Bridge Farm Close

(Figure 5.2). Additonally, this chapter includes analyses of river discharge records. All discharge records (and 15 minute rainfall data analysed in this chapter) were provided by the Environment Agency. Further information on this analysis is included in Section 3.7.2 of the Methodology, and details of the nature of the analysis and descriptions of the gauging station records utilised are contained in Tables 3.8 and 3.9 respectively. The upper Ryedale daily rainfall record (as analysed in detail within Chapter 4) is also used within this chapter, and contains data downloaded from the Met Office MIDAS Land Surface Stations database (National Centre for Atmospheric Science, British Atmospheric Data Centre, 2006); some snowfall data used in this chapter is also derived from this source. Figure 5.1 shows the locations of places referred to in the chapter text.

Section	Description of content
5.1	Summary of the experience of flash flooding in 2005 among residents of Helmsley
5.2	Responses to flash flooding of residents from Helmsley as a whole, and the factors affecting them
5.3	Responses to flash flooding of residents throughout upper Ryedale who were direct affected by flooding in 2005, and the factors affecting them
5.4	Assessment of relationships between river discharge and rainfall, and the identification of possible past floods using the upper Ryedale rainfall series
5.5	Description of perceived factors influencing local flood risk
5.6	Chapter summary

Table 5.1: Summary of the structure and contents of Chapter 5.

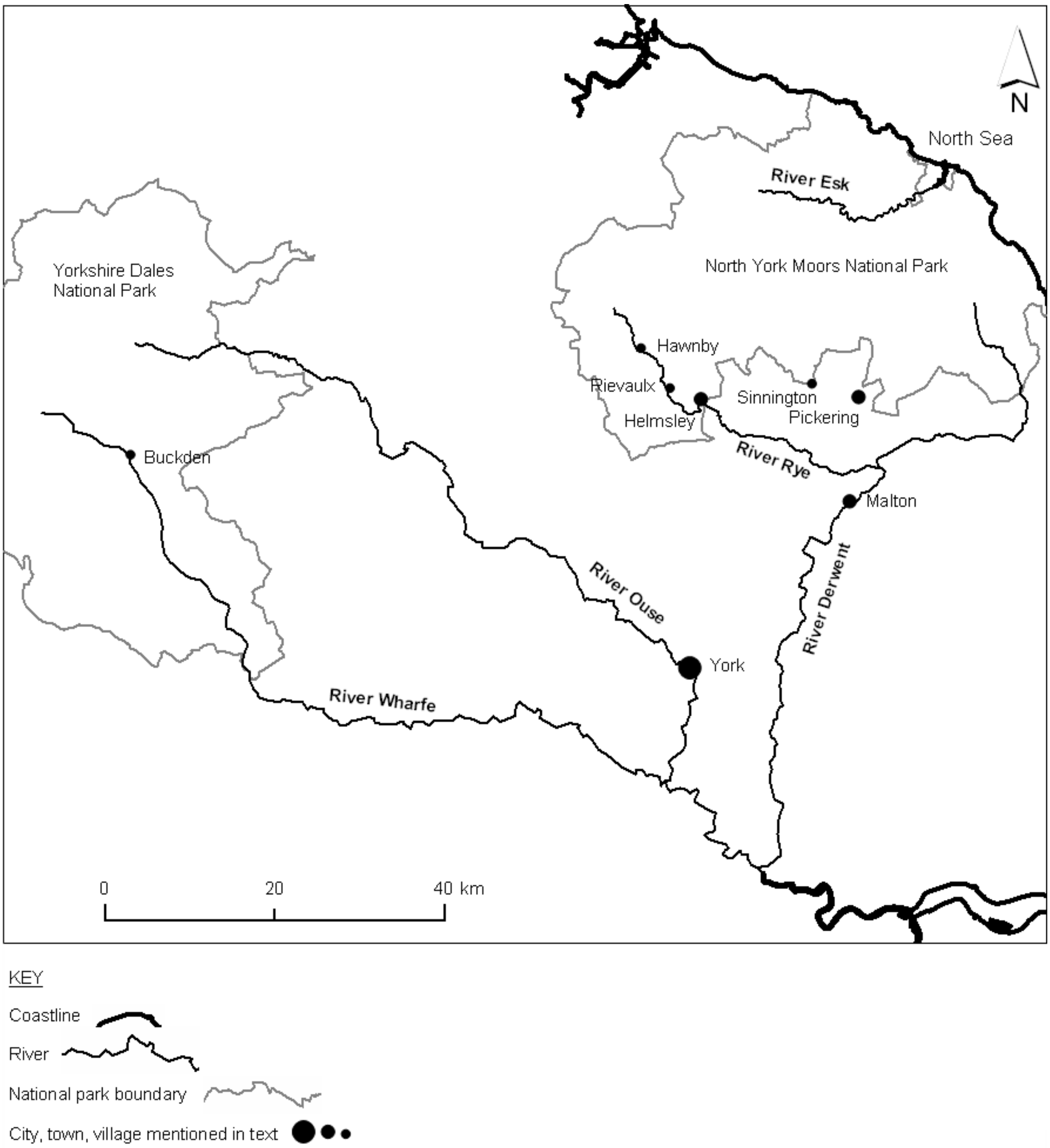


Figure 5.1: Location map showing places referred to in the chapter text. Diagram contains Ordnance Survey Strategi® data: © Crown Copyright/database right 2011. An Ordnance Survey/EDINA supplied service.

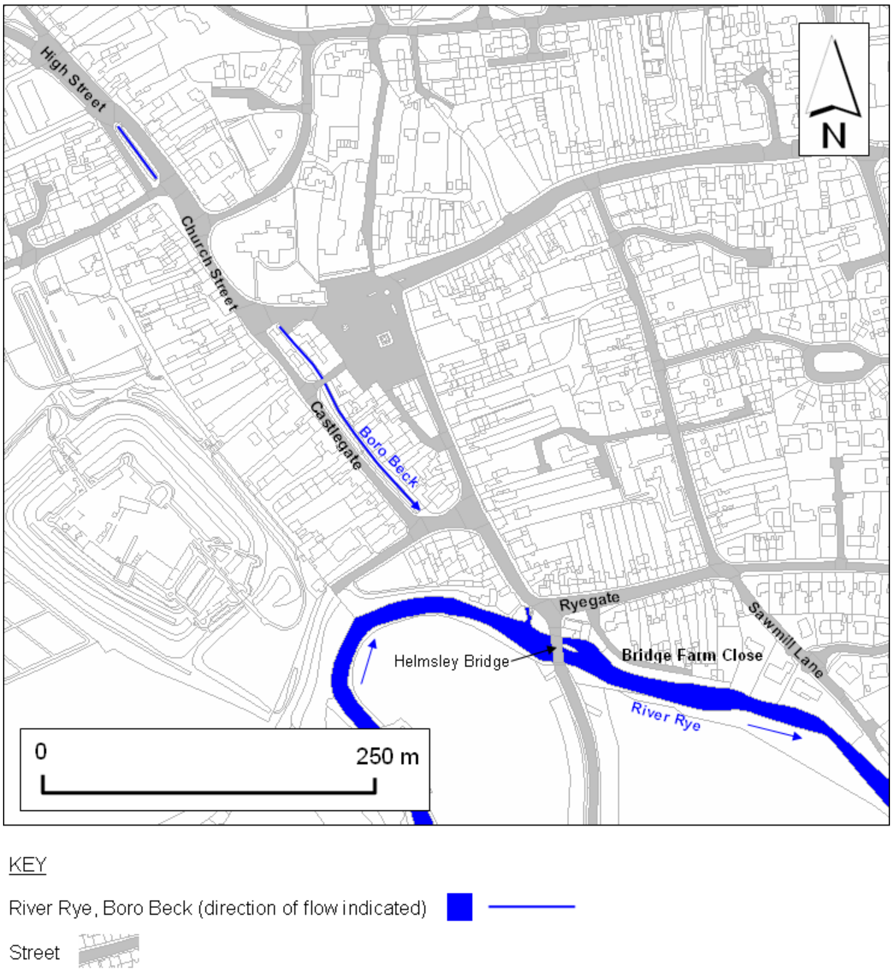


Figure 5.2: Map showing central and southern Helmsley, showing the streets where interviews took place in Helmsley (Ryegate, Sawmill Lane and Bridge Farm Close) as well as other parts of Helmsley referred to in this chapter. Diagram contains Ordnance Survey MasterMap® data: © Crown Copyright/database right 2011. An Ordnance Survey/EDINA supplied service.

5.1 Experience of flash flooding in 2005

The questionnaire attempted to assess the spatial pattern of flood impacts in the town of Helmsley. Of all questionnaire respondents, less than a quarter replied that they had been affected by the 2005 flash flood in Helmsley. 5.3% stated that they had been 'directly' affected (floodwater causing damage to their possessions, following the definition by Penning-Rowsell and Chatterton (1977)), with a further 17.8% agreeing that they were ‘indirectly’ affected by flooding (having their standard of living or wealth influenced by the flood, again approximating a definition by Penning-Rowsell and Chatterton (1977)) (n = 152). Directly affected respondents were concentrated in a small area comprising the southern side of Ryegate, Sawmill Lane, and Bridge Farm Close below Ryegate (Figure 5.2).

Despite the low number of people affected by the flood, nearly three-quarters of survey respondents witnessed the flash flood, and four out of five respondents knew someone who was directly affected by the flood (Table 5.2). Additionally, a quarter of residents agreed that they were involved in some way with the cleanup following the flood. It is clear that although the flood directly affected a very low number of people, a large part of the Helmsley community as a whole was heavily involved in dealing with the flood event and observed the flood taking place.

	No	Yes	n
Did you personally witness the flood in Ryedale in June 2005?	26	74	154
Do you have any friends or relatives (or know anyone else) who was directly affected by the June 2005 flood?	19.6	80.4	148
Know any friends who were directly affected?	49.3	50.7	148
Know any relatives who were directly affected?	90.5	9.5	148
Know any others who were directly affected?	73.6	26.4	148
Were you involved in any way with the cleanup after the June 2005 flood?	76.5	23.5	149

Table 5.2: Questionnaire respondents’ experiences of the 2005 flash flood event. No, Yes figures are percentages.

5.2 Responses to flash flooding of Helmsley residents, and factors influencing them

5.2.1 Responses to flash flooding

It is notable that the awareness of Environment Agency warning services was extremely low in Helmsley (Table 5.3). Although no telephone warning service was provided by the Environment Agency to the residents of upper Ryedale, Floodline was the most well-known of the flood information services, with just under half of respondents agreeing that they had "...heard of this and know what it is". Flood warning symbols were particularly poorly known: over four out of ten respondents had never heard of them and an additional three in ten did not know what they were despite having heard of them. Flood maps had been used by one-in-ten of all questionnaire respondents, although over a third (34.3%) of respondents had never heard of the maps before and over half of respondents did not know what the maps were (Table 5.3).

	1	2	3	4	n
Knowledge of flood warning symbols	40.7	30.7	26.4	2.1	140
Knowledge of Floodline	17.4	31.2	49.3	2.2	138
Knowledge of flood maps	34.3	21.6	33.6	10.4	134

Table 5.3: Responses to flooding by questionnaire respondents: knowledge of flood information services provided by the Environment Agency. Numbers 1-4 correspond to the following statements: 1 - "I have never heard of this before", 2 - "I have heard of this, but am not sure what it is", 3 - "I have heard of this and know what it is", 4 - "I have used this service before". Figures in columns 1-4 are percentages.

Furthermore, awareness and knowledge of flood warning services in Helmsley did not differ greatly between those located in areas of higher assessed flood risk and those of lower flood risk. 45.7% of all questionnaire respondents lived within flood risk zone 3 (the area with a greater than one in 100 risk of flooding, annually (Department for Communities and Local Government, 2006)). 5.7% of individuals located within flood zone 3 had used the Floodline service before (n = 53) compared with 0% of those living outside the flood risk zone (n = 59). Similarly, a higher percentage of individuals living within flood zone 3 had used the Environment Agency's flood maps before (11.3%, n = 63) compared with those living outside the zone (8.9%, n = 56). However, the proportion of individuals with complete ignorance of flood maps (having never heard of the service before) was actually higher in flood risk zone 3 (35.8%) than outside the zone in areas of lower assessed flood risk (25%). A similar pattern occurred with knowledge of flood warning symbols, with 43.4% of respondents who lived within flood zone 3 having never heard of the symbols before (n = 53), a greater proportion than the 34.4% of respondents situated outside flood zone 3 (n = 61).

Since the flood in 2005, majorities of residents had become more aware of weather forecasts and river and stream levels (Table 5.4). Additionally, six out of ten respondents had discussed flooding with other residents, suggesting a general increase in awareness of the environment since the flood.

	No	Yes	n
Since the flood in 2005, are you more aware of weather forecasts than you used to be?	38.1	61.9	147
Since the flood in 2005, are you more aware of river and stream levels than you used to be?	28.6	71.4	147
Since the flood in 2005, have you discussed flooding with other residents?	40.3	59.7	154

Table 5.4: Responses to flooding by questionnaire respondents: 'awareness' variables. No and Yes figures are percentages.

When asked to evaluate the preparedness of a) people who are likely to be affected by a future flood, and b) the local authorities to a hypothetical reoccurrence of the 2005 flood, respondents generally showed more faith in the local authorities than people likely to be affected by flooding (Table 5.5). The answers to this question were split quite evenly across the three categories, but suggested a pessimism about the preparedness of the local community in the event of future flooding, as only approximately a quarter of respondents agree that either of these groups are prepared for future flooding (Table 5.5).

	Disagree	N.A.N.D.	Agree	n
If a similar flood occurred again, people who are likely to be affected are prepared to deal with it	39.6	38.9	21.5	149
If a similar flood occurred again, the local authorities are prepared to deal with it	36	38	26	150

Table 5.5: Responses to flooding by questionnaire respondents: opinions of local preparedness for future flooding. 'N.A.N.D.' stands for 'Neither agree nor disagree'. Disagree, N.A.N.D. and Agree figures are percentages.

5.2.2 Factors influencing responses to flash flooding

Table 5.6 summarises the questionnaire variables found to have statistically significant associations with responses to flash flooding. These are analysed in more detail in the sections below. Where an overall test result is given in brackets, this refers to the non-parametric test result between two variables, and not any subsets of the data.

*Table 5.6 (next two pages): Summary of questionnaire variables showing statistically significant associations with responses to flash flooding, and details of the non-parametric tests used. Only those variables with significant associations with flash flood response variables are listed (in rows). Grey boxes indicate a statistically significant association with p-value<0.05. Blue boxes indicate a statistically significant association with p-value<0.01. Arrows indicate changes to the likelihood of responses, based upon the description of the variable in each row (for instance: respondents who perceive a higher future flood risk are more likely to be more aware of river levels since the flash flood in 2005). No arrow shows an interpreted lack of changes to responses, despite a statistically significant association between variables. For chi square tests, χ^2 - chi square test result. * - Continuity Correction value used due to 2x2 table involved in calculation. df - degrees of freedom. n - number of values in calculation. p - statistical significance. ex - first value shows number of cells with expected count lower than 5, second value shows minimum expected count. Other tests: M-W U - Mann-Whitney U test. U - U statistic. K-W - Kruskal-Wallis test (which returns a χ^2 value).*

	Knowledge of Environment Agency services			Actions/awareness since 2005 flood			Preparedness of community	
	Warning symbols	Floodline	Flood risk maps	Discussed flooding	Weather forecasts	River levels	Residents	Local authorities
As respondents get older:		↓ M-W U U = 694 n = 93 $p = 0.004$						
If there are children living at home (rather than no children):		↑ Chi square $\chi^2 = 4.316$* df = 1 n = 128 $p = 0.038$ ex = 0, 9.84						
If there is more than one adult living at home (rather than just one):		↑ Chi square $\chi^2 = 5.650$* df = 1 n = 128 $p = 0.017$ ex = 0, 22.03	↑ Chi square $\chi^2 = 5.442$* df = 1 n = 125 $p = 0.02$ ex = 0, 18.66					
As respondents live further away from the river:								↑ K-W $\chi^2 = 9.579$ df = 2 n = 124 $p = 0.008$
If respondents perceive a high future flood risk (rather than low):						↑ Chi square $\chi^2 = 6.694$ df = 2 n = 138 $p = 0.035$ ex = 1, 3.48		
If respondents agree that floods of the River Rye were getting worse (rather than disagree):				↑ Chi square $\chi^2 = 6.838$ df = 2 n = 148 $p = 0.033$ ex = 0, 17.31		↑ Chi square $\chi^2 = 6.290$ df = 2 n = 142 $p = 0.043$ ex = 0, 11.27	↓ Chi square $\chi^2 = 12.519$ df = 4 n = 146 $p = 0.014$ ex = 0, 8.77	↓ Chi square $\chi^2 = 10.053$ df = 4 n = 146 $p = 0.04$ ex = 0, 10.41
If respondents agree that floods were getting worse on other streams (rather than disagree):					↑ Chi square $\chi^2 = 6.635$ df = 2 n = 142 $p = 0.036$ ex = 0, 10.85			

	Knowledge of Environment Agency services			Actions/awareness since 2005 flood			Preparedness of community	
	Warning symbols	Floodline	Flood risk maps	Discussed flooding	Weather forecasts	River levels	Residents	Local authorities
If respondents witnessed the 2005 flood (rather than not):	↑ Chi square χ^2 = 4.196* df = 1 n = 140 p = 0.041 ex = 0, 10.29							Chi square χ^2 = 6.167 df = 2 n = 150 p = 0.046 ex = 0, 10.14
If respondents were involved with the cleanup after the 2005 flood (rather than not):	↑ Chi square χ^2 = 4.963* df = 1 n = 136 p = 0.026 ex = 0, 9.46	↑ Chi square χ^2 = 4.968* df = 1 n = 134 p = 0.026 ex = 0, 16						
As respondents recall more floods:					↓ M-W U U = 2071 n = 145 p = 0.041			
If respondents perceive that winters have got wetter (rather than drier):	↑ Chi square χ^2 = 14.718 df = 2 n = 126 p = 0.001 ex = 0, 11.39				↑ Chi square χ^2 = 7.718 df = 2 n = 132 p = 0.021 ex = 0, 15.96	↓ Chi square χ^2 = 10.599 df = 2 n = 131 p = 0.005 ex = 0, 11.22	↓ Chi square χ^2 = 10.482 df = 4 n = 133 p = 0.033 ex = 0, 9.47	↓ Chi square χ^2 = 11.302 df = 4 n = 133 p = 0.023 ex = 0, 11.37
If respondents perceive that springs have got wetter (rather than drier):					↑ Chi square χ^2 = 6.381 df = 2 n = 129 p = 0.041 ex = 0, 8.19	Chi square χ^2 = 7.656 df = 2 n = 128 p = 0.022 ex = 0, 5.84		
If respondents perceive that prolonged rainfall was occurring more often (rather than less often):					↑ Chi square χ^2 = 10.985 df = 2 n = 134 p = 0.004 ex = 0, 6.72			

5.2.2.1 Knowledge of Environment Agency flood warning and flood information services

Demographic variables (having children living at home, having more than one adult living at home, and age), and experience of flooding in 2005 (witnessing the 2005 flash flood event, and being involved with the cleanup after the flash flood) were found to be associated with residents' knowledge of services provided by the Environment Agency (Table 5.6). Questionnaire respondents with children living at home were more likely to know what Floodline was, compared with those who did not have children living at home (χ^2 = 4.316, p = 0.038, n = 128). Those who lived in a house with more than one adult living in it were more likely to know what Floodline was, compared with those who lived alone (χ^2 = 5.650, p = 0.017, n = 128): 62% of those who lived in a house with more than one adult living in it knew what Floodline was, compared with 38% of those living alone. A similar association existed regarding the awareness of flood risk maps, as those with more than one adult living at home were more likely to know what the flood risk mapping was (χ^2 = 5.442, p = 0.02, n = 125). Residents who knew what Floodline was were more likely to be younger than those people who did not know what the service was, in a highly statistically significant association (Mann-Whitney U = 694, p = 0.004, n = 93). Therefore, respondents with families appeared more likely to have knowledge of flood warning and information services than those without.

Additionally, experience of flash flooding was also associated with knowledge of Environment Agency services (Table 5.6). Involvement with the cleanup following the 2005 flood was associated with knowledge of Floodline, as 69% of those who had been involved with the cleanup following the 2005 flood knew what Floodline was, however knowledge of Floodline declined to 44% amongst those not involved with the cleanup (χ^2 = 4.968, p = 0.026, n = 134). Similarly, involvement with the cleanup following the flash flood was associated with knowledge of flood warning symbols (χ^2 = 4.963, p = 0.026, n = 136), and witnessing the flash flood event was also associated with knowledge of the symbols (χ^2 = 4.196, p = 0.041, n = 136); although the warning symbols were not well-known generally, knowledge of them increased from 14% among those who had not witnessed the 2005 flash flood to 34% among those who had seen the flood. Finally, perceived change to winter rainfall was strongly associated with knowledge of what warning symbols were (χ^2 = 14.718, p = 0.001, n = 126): those who felt that winters have become wetter tended to be more likely to know what the warning symbols were.

5.2.2.2 Actions taken since the 2005 flood

Respondents' perceptions of local trends in flooding, knowledge and experience of past flooding and respondents' views on trends in local rainfall were associated with actions taken by respondents since the 2005 flash flood (Table 5.6). Respondents' views on whether flooding of the River Rye was getting worse were associated with the discussion of flooding with other residents (χ^2 = 6.838, p = 0.033, n = 148): respondents who felt that flooding of the River Rye was getting worse were more likely to have discussed flooding with other residents than those who did not think that flooding of the Rye was getting worse. Additionally, respondents' perceptions of future flood risk in upper Ryedale were associated with changed awareness of river levels since the 2005 flash flood (χ^2 = 6.694, p = 0.035, n = 138) and views on whether flooding of the River Rye was getting worse or not were also associated with awareness of river levels (χ^2 = 6.29, p = 0.043, n = 142). Those with higher perceptions of flood risks were more likely to be more aware of river levels since the flash flood.

Three variables related to respondents' perceptions of rainfall have statistically significant associations with awareness of weather forecasts after the 2005 flash flood. Firstly, if residents perceive that winters have got wetter, they are more likely to be more aware of weather forecasts since the 2005 flash flood, than those who believe that winters have got drier ($\chi^2 = 7.718$, $p = 0.021$, $n = 132$). Secondly, if residents believe that springs have got wetter, they were more likely to state that they were more aware of weather forecasts since the flood than those who believed that springs had got drier ($\chi^2 = 6.381$, $p = 0.041$, $n = 129$). Finally, those who perceived that prolonged rainfall events were occurring more often were more likely to state that they were more aware of weather forecasts than those who perceived that such events were occurring less often ($\chi^2 = 10.985$, $p = 0.004$, $n = 134$). Furthermore, changed awareness of weather forecasts was significantly associated with the total number of floods that respondents could recall (Mann-Whitney $U = 2071$, $p = 0.041$, $n = 145$): those who were more aware of weather forecasts since the 2005 flash flood tended to have heard of fewer floods than those less aware of forecasts. There was also a statistically significant association between perceived change to local floods (from other streams) and awareness of weather forecasts ($\chi^2 = 6.635$, $p = 0.036$, $n = 142$), as those respondents who perceived that floods from other streams were getting worse were more likely to show increased awareness of weather forecasts following the 2005 flash flood.

5.2.2.3 Perceived preparedness of residents and local authorities

Finally, the questionnaire asked for respondents' opinions on the preparedness of two groups for future flooding (a hypothetical, similar flood to 2005): residents likely to be affected by future floods, and the local authorities. There was a significant association between respondent location (the distance of their house from the River Rye), and perceived preparedness of local authorities to deal with future flooding: respondents who agreed that the local authorities were prepared for future flooding tended to be more likely to live further away from the river ($\chi^2 = 9.579$, $p = 0.008$, $n = 124$). Aside from this, beliefs in the preparedness of local authorities and residents to deal with a future flood appeared to be associated with two variables: perceptions of the trend in local river flooding, and perceptions of winter rainfall. Those who felt that floods of the River Rye were getting worse were less likely to agree that residents, and local authorities were prepared for future flooding (respectively, $\chi^2 = 12.519$, $p = 0.014$, $n = 146$ (residents); $\chi^2 = 10.053$, $p = 0.04$, $n = 146$ (local authorities)). To illustrate, among those who disagreed that flooding of the River Rye was getting worse, 43% agreed that the local authorities were prepared to deal with a future flood (and 30% disagreed). Among those who agreed that flooding of the Rye was getting worse, these figures change to 18% agreeing and 47% disagreeing. Finally, perceptions of changes to winter rainfall were associated significantly with views of the preparedness of residents and local authorities for future flooding (respectively, $\chi^2 = 10.482$, $p = 0.033$, $n = 133$ (residents); $\chi^2 = 11.302$, $p = 0.023$, $n = 133$ (local authorities)). Those who perceived that winters had got wetter tended to be less likely to believe that residents and the local authorities were prepared for a future flood. For instance, 33% of those who believed that winters had got drier agreed with the view that residents likely to be affected by flooding would be prepared for a similar flood to the 2005 flood (36% disagreed). However, among those respondents who believed that winters had got wetter, these figures changed to 17% agree and 52% disagree.

Questionnaire respondents were additionally asked to provide a longer answer if they disagreed that residents or the local authorities were prepared to deal with a similar flood to 2005. In total, 49 respondents did so and their responses are summarised in Table

5.7. The most commonly-used explanation for the lack of preparedness of these groups was a lack of action (suggested as a factor in 40% of responses). The next two most commonly-provided factors are related to perception of risk: lack of preparedness due to the belief that the flood was a one-off event (mentioned in 18.4% of responses) and a belief that nothing can be done to stop flood damages (14.3% of responses). Financial issues were mentioned by one in ten respondents, particularly in relation to a lack of preparedness of local authorities. Further factors, including the vulnerability of some groups to flooding (older people, those who had just moved to the area), were much less commonly mentioned.

Factor	% of responses mentioning factor
Lack of action	40.8
Belief that the flood was a one-off	18.4
Belief that nothing can be done to prevent flood damages	14.3
Lack of money	10.2
Old people	
New residents not as aware of flood risk	
Flood damage/problems sorted in the past	all 4.1
Don't know what to do to prepare	2.0

Table 5.7: Factors influencing the lack of preparedness of at-risk residents and local authorities for future flooding in upper Ryedale, according to questionnaire responses (n = 49).

5.2.2.4 Factors influencing flood hazard perception

Hazard perception variables (in particular, opinions of the future probability of flooding of the River Rye) and flood experience (the number of past floods recalled, as well as experience of the 2005 flash flood) were found to be associated with certain responses to the 2005 flash flood. A separate analysis of the variables associated with the flood risk perceptions of Helmsley residents was undertaken (Table 5.8). The distance of the respondent's house from the River Rye is significantly associated with the views of the nature of the 2005 flash flood event. Those who agreed that the flash flood of 2005 was a one-off event were more likely to live closer to the River Rye, on average, than those who did not think that the flash flood was a one-off (χ^2 = 6.656, p = 0.036, n = 124). Additionally,certain types of indirect experience of the 2005 flash flood were associated with respondents' opinions on whether the flash flood was a one-off event or not. Those who knew someone who had been directly affected by the flash flood were more likely to view the flash flood event as a one-off event, than those respondents who did not know someone directly affected (χ^2 = 6.896, p = 0.032, n = 146). Additionally, respondents who were involved with the cleanup after the flash flood (rather than not being involved) were more likely to think that the 2005 flash flood would not happen again (χ^2 = 7.79, p = 0.02, n = 147). Furthermore, involvement with the cleanup following the 2005 flash flood was significantly associated with two additional variables related to perceived trends in local flooding. Those involved in the cleanup following the 2005 flash flood were less likely to agree that flooding of the River Rye was getting worse (χ^2 = 6.636, p = 0.036, n = 144) or perceive that flooding from other streams was getting worse (χ^2 = 12.849, p = 0.002, n = 144) than those who were not involved in the cleanup following the flood.

Therefore, experiences with the 2005 flood are associated with decreased flood risk perception. Overall flood experience and knowledge (the total number of recent floods, in the 1990s and 2000s, that residents could recall) was associated with perceptions of changes to local flood risks. Those respondents who agreed that flooding of the River Rye, and local surface water flooding were getting worse, tended to recall a greater number of recent floods (events in the 1990s and 2000s) than those who did not perceive an increasing trend in flooding (respectively, χ^2 = 6.975, p = 0.031, n = 146 (flooding of the River Rye); χ^2 = 10.646, p = 0.005, n = 145 (surface water flooding)).

	2005 flood = one-off event	Likelihood of flood in Upper Ryedale in next ten years	Flooding of the River Rye is getting worse	Flooding from other streams in Ryedale is getting worse	Surface water flooding in Ryedale is getting worse
If respondents were in work (rather than retired):		↓ Chi square χ^2 = 6.988 df = 2 n = 112 p = 0.03 ex = 0, 5.04	Chi square χ^2 = 14.681 df = 2 n = 114 p = 0.001 ex = 0, 13.72	↓ Chi square χ^2 = 9.401 df = 2 n = 114 p = 0.009 ex = 0, 9.28	
As respondents live further away from the river:	↓ K-W χ^2 = 6.656 df = 2 n = 124 p = 0.036	K-W χ^2 = 7.109 df = 2 n = 118 p = 0.029			
If respondents know someone directly affected by flooding in 2005 (as opposed to not knowing someone):	↓ Chi square χ^2 = 6.896 df = 2 n = 146 p = 0.032 ex = 0, 6.55				
If respondents were involved with the cleanup after the 2005 flood (rather than not):	↓ Chi square χ^2 = 7.790 df = 2 n = 147 p = 0.02 ex = 0, 7.17		↓ Chi square χ^2 = 6.636 df = 2 n = 144 p = 0.036 ex = 0, 9.4	↓ Chi square χ^2 = 12.849 df = 2 n = 144 p = 0.002 ex, 0, 6.19	
As respondents recall more recent (1990s, 2000s) floods:			↑ K-W χ^2 = 6.975 df = 2 n = 146 p = 0.031		↑ K-W χ^2 = 10.646 df = 2 n = 145 p = 0.005
If respondents perceive that winters have got wetter (rather than drier):			Chi square χ^2 = 12.664 df = 4 n = 133 p = 0.013 ex = 0, 12.32		

Table 5.8: Summary of questionnaire variables showing statistically significant associations with flood risk perceptions among questionnaire respondents, and details of the non-parametric tests used. Only those variables with significant associations with perception variables are listed (in rows). Grey boxes indicate a statistically significant association with p-value<0.05. Blue boxes indicate a statistically significant association with p-value<0.01. Arrows indicate changes to the likelihood of responses, based upon the description of the variable in each row (for instance: respondents who were in work, rather than retired, were more likely to perceive a low likelihood of a flood occurring in upper Ryedale in the next ten years). Note that the direction of the arrows for the "2005 flood = one-off event" category is reversed, as being more likely to believe that a flash flood is a one-off event constitutes a lower perception of flood risks. No arrow shows an interpreted lack of changes to responses, despite a statistically significant association between variables. For chi square tests, χ^2 - chi square test result. df - degrees of freedom. n - number of values in calculation. p - statistical significance. ex - first value shows number of cells with expected count lower than 5, second value shows minimum expected count. K-W - Kruskal-Wallis test (which returns a χ^2 value).

5.2.3 Summary of factors influencing responses to flash flooding

Among the population of Helmsley sampled by the questionnaire, it appeared that certain sets of variables (demographic characteristics, local knowledge and experiences, and perceptions) were associated with responses to flash flooding. Further analysis of these associations suggests the following central findings:

- Families (houses with children and more than one adult living in them) were more likely to be aware of the flood warning and information services provided by the Environment Agency. Additionally, people who witnessed the flash flood or were involved in the cleanup after the flood were more likely to know what these services were.

- Awareness of local river levels was most likely to increase among respondents who believed that flooding of the River Rye was getting worse, or perceived a high risk of another flood occurring within ten years. Perceptions of changes to local floods (from other streams) were associated with changes to the awareness of weather forecasts, as were perceptions of changes to certain aspects of local rainfall. By contrast, respondents who had become more aware of weather forecasts tended to recall lower numbers of floods.

- Those who believed that floods of the River Rye were getting worse, and who believed that winters had got wetter, were less likely to believe that residents or local authorities were prepared for future flooding. Residents who believed that residents and local authorities were prepared for a hypothetical future flood tended to live further away from the River Rye, on average. Questionnaire respondents typically felt that there had been a lack of action after the 2005 flash flood, with other factors contributing to the lack of preparedness including a belief that the flood was a one-off event, and a view that flood damages are inevitable.

5.3 Responses to flash flooding of households directly affected by flash flooding, and factors affecting them

Members of nine households where floodwater entered the property in 2005 were interviewed: seven households in Helmsley, one in Rievaulx and one in Hawnby (Figure 5.1). Based upon communications with residents in interviews, experiences of flooding in these areas varied considerably. Most of the interviewees in Helmsley were able to leave their houses, or get to the upper levels of their houses relatively easily, although there was more concern for the welfare of older residents. However, in the more isolated communities of Hawnby and Rievaulx, access for the emergency services was much more difficult due to damage to bridges above Helmsley, which also prevented other residents coming to the aid of others. The experience of flooding upriver of Helmsley was considerably more distressing. An interviewee in Hawnby, whose business premises (kennels) were situated alongside the River Rye, had to rescue his wife from the floodwaters as well as a number of the animals in his kennels (two dogs were lost). At the time of interview, in 2008, he estimated that his level of business was approximately half what it was prior to the floods, due to a reduction in his customer base.

5.3.1 Summary of responses to flash flooding

Responses to the 2005 flash flood can be split into two categories - physical changes to properties, and changes to interviewees' behaviour since the 2005 flash flood.

5.3.1.1 Physical modifications

In total, five out of the nine households interviewed had made some physical modifications to their house or land to prevent or reduce future flood risk, with one further property considering the purchase of air brick covers. Three of these six houses had made modifications prior to the 2005 flood. These tended to be located directly alongside the River Rye, and only a small altitude above it. In the autumn of 2000, a flood (much smaller than that in 2005) caused the River Rye to burst its banks. Clearly it affected a more limited area than 2005, but an interviewee detailed that it had flooded one house. This house had also been flooded 20-30 years prior to interview (possibly in the 1980s, although another timing c. 50 years ago was given later in the interview), and as such the house's interior was designed with the ground (lower) floor largely kept empty and the upper floor used as the living space (Figure 5.3).

> ...Before that (2000 flood) it hadn't flooded for about twenty/thirty years, apparently, which is why this house was built upside down. It has got a big basement downstairs and then the lounge and bedrooms are on this (upper) level.

Figure 5.3: Two adaptations to flooding at a house in Helmsley. Top: the lower floor of the house, not used as a living space and largely cleared out of valuables. Bottom: a wooden barricade.

The household had made two other modifications following the flooding in the year 2000. Firstly, some French doors at the back of the house had been bricked up. Secondly, some wooden home-made barricades had been made to place at the bottom of doors (Figure 5.3). However the flash flood in 2005 arrived too quickly for the barricades to be put up, and the need to be able to anticipate a flood's arrival in advance presents a major restriction upon using such barriers in pluvial, or flash floods that arrive quickly (Douglas et al., 2010). Similarly, another resident of Helmsley was given sandbags to use three to four years before the 2005 flash flood, as the river was rising. However, similar to the barricades mentioned above, the sandbags were not useful for dealing with the 2005 flash flood:

…The council came round with some sandbags. Because there was no chance to come into the house, we didn't think, we just stored them in the shed, and then in 2005 when we wanted them they were all rotten. We went for them and they just fell to bits.

The third household to have made physical modifications to protect against flooding prior to the 2005 flood was also located in Helmsley. Prior to the 2005 flood, a family member had built the nearby river bank up to a higher level (Figure 5.4) with the bank being built higher again following the flood. The interviewees from this household believed that the raised river bank had helped to protect them from flooding in 2005:

This is a private flood defence.

It's just the river bank really, we built it up with soil.

Do you think it helped in 2005?

Oh yes, definitely.

If it hadn't been for that, much more water would have got from the river into the house then?

No doubt.

Figure 5.4: The raised river bank of the River Rye, work completed prior to the 2005 flash flood, built between the River Rye and the houses in Bridge Farm Close and Ryegate in Helmsley.

One other household in Helmsley had been modified following the 2005 flood: a wall at the rear of the property was rebuilt much higher than it was before the flood, and a vent (where the floodwaters had entered in 2005) had also been removed. However, the most costly physical modification was undertaken in Hawnby, where the owner of some boarding kennels suffered widespread damage to his house and business premises, to the extent that he had to rebuild them at a higher elevation further away from the river (Figure 5.5). The main reason for this was that his insurance company would refuse to insure the damaged property if it was restored, which would mean that he would be unable to sell the property. Secondly, he was concerned about the impact on his business if he remained in the original premises:

...Having lost a couple of animals, I didn't think that people would bring their animals out here if they'd knew it was next to the river and there was a chance it (a flood) could happen again.

Figure 5.5: The interviewee's former house remains (unoccupied) at Hawnby in 2008, with the interviewee's new property visible at a higher altitude. In the foreground is a bridge over the River Rye.

Finally, at the time of interview (summer 2008), a couple living in Helmsley had conducted a large amount of research into air brick covers and 'smart bricks' (a product available called the Smart Airbrick®) as well as door and window covers. They implied that they were likely to get the air brick covers in the future. In 2005, water had entered their property via the air bricks, so they viewed this as a logical modification to make to their property. However they were less enthusiastic regarding the purchase of door and window covers. They had also successfully lobbied the Environment Agency to clear some debris from the River Rye at the back of their property:

…For various reasons, (name) persuaded the Environment Agency that this lump of rock was causing erosion on our side of the bank and all the way down. She got them to dredge it. They took out a huge amount of stone and streamlined the river up, and the water now, it's only the second time since the flood it has been up that high, so I think because they've actually looked after the river and done some dredging the water gets away quicker.

5.3.1.2 Behavioural changes

Seven out of the nine households who were directly affected by the flash flood in 2005 had changed their behaviour following the flood in some way, in order to account for flood risk. In five households, interviewees remarked that they were more aware of river levels since the 2005 flash flood, with four interviewees stating that they have a personal 'worry level', a reference point which when reached by the river, residents would begin to take action to protect their house from flooding. One resident had monitored river levels for a while (prior to the 2005 flood) by using some sandstone blocks on Helmsley Bridge (Figure 5.2):

Okay. Before the 2005 flood, did you think that a flood could happen from the river?

No. I could see it rise because I'd measure it against the stones, but I've never seen it very high.

You say the stone, how do you do it?

I'd have to take you out to show you. You can't see the river from here, but I have a measure on the side of the bridge.

In two interviews, there were mentions of a 'worry level' and a 'panic level', situated on some steps and at the top of a wall in the gardens of two houses, respectively:

I would worry when it (the river level) got to the top of the wall. If you go down the garden, you'll see there's another foot to eighteen inches before it gets to the top of the bank. If it got to the top wall, I'd start to worry a bit then.

Most of the interviewees therefore stated that they observed river levels more frequently since the 2005 flash flood, and that they were more aware when the river level was high. This was picked up on by other residents; a resident unaffected by flooding in 2005 suggested that people were watching the river more often, particularly after heavy rain:

> No, see because from my bedroom window... the river is quite low, but people do watch now, I often see people having a look over the bridge, to see how high it is, all sorts of people, have a look over there, who was it the other day... when we had a lot of rain, she was looking over quite anxiously...

An increased awareness of heavy rainfall events was in evidence, as three of those directly affected by flooding in 2005 mentioned that they were observant of when heavy rain fell. One resident kept a rain gauge in his garden as part of a long-term interest in monitoring rainfall. Another resident stated that when heavy rain occurred since the 2005 flood, he would bring his dog in from its kennel (which was close to the river). Another resident, who had lived locally since 1943 stated that his experience of living in the area meant that he was able to approximately estimate flood risk from rainfall:

> Well I go more on the rainfall, than watching the river level. I look at what's fallen, and how long it sort of takes to build up coming down from Bilsdale (a valley in the uplands of the Rye catchment), and that. I'm more experienced that way, like. I don't particularly just watch the river level, I know when to be looking, like.

Four households directly affected by flooding said that they tended to keep valuables and important possessions at a higher level. Three of these households stated that they did this more since the 2005 flood, while one resident said that he did this prior to the 2005 flood, as the shed where he kept his tools was situated near the River Rye. Also, two residents directly affected in 2005 stated that they watched the weather forecasts more often than they used to prior to the 2005 flood.

With regard to awareness of the Environment Agency's flood information and warning services, five out of the nine households were aware of what Floodline was. Four of the nine were aware of flood maps and two out of the nine were aware of flood warnings and warning symbols. Although the number of directly affected households surveyed was low, among directly affected residents the uptake of these services appeared to be higher than among the population of Helmsley as a whole. However, many of the residents who had used the services were unhappy with them. For instance, one resident had telephoned the Environment Agency on the 19th June 2005, as the River Rye was rising following the heavy rainfall. Remarkably, she was reassured that there was nothing to worry about:

I didn't see (name) until the rain had stopped, by which time I'd rung flood alert and said the river is rising very fast. The girl said 'Don't worry, love, it has stopped raining now', and that was the end of the discussion.

A couple living in Helmsley had also used Floodline. However, they felt that the Environment Agency was a remote organisation which was unaware of local concerns and situations:

Floodline, you get it now on the television, 'If you're anxious ring Floodline'. You actually get through to a central office in somewhere like Leeds. As (name) said, they have no idea of the local situations. The names mean nothing to them, and I doubt very much whether some of our neighbours know the nearest warning to us is at Broadway Foot.

Additionally, the resident of Hawnby who was directly affected by flooding said that now he had moved his property further away from the river, the Floodline service did not make any difference. As with the population of Helmsley as a whole (sampled by the questionnaire), the flood maps and flood warning symbols were less well known than the Floodline warning service. It was particularly notable that the two residents of one household misidentified the warning symbols as road warning signs (another resident who was not directly affected by the flash flood also made the same comment):

Whereabouts have you seen them (warning symbols), then?

Male: Er, erm, well they are on the road isn't there?

Female: Just on the roadside, it said flood. Just a little one, it said flood. I mean...

Flood maps had also been used by some residents. For example, a resident unaffected by flooding in 2005 had accessed the flood maps on the Environment Agency's website and ascertained that he was not at risk of flooding. However, the knowledge of the services provided by the Environment Agency was far from universal, even among those directly affected by flash flooding in 2005.

5.3.2 Factors influencing responses to flash flooding

A wide range of responses to the flash flood of 2005 were observed among those directly affected by the floodwaters. It is clear that most of the responses were behavioural in nature (e.g. being more observant of river levels, keeping valuables at higher levels) rather than physical modifications to properties.

In Helmsley, the residents that had made the largest modifications to their properties and to their own behaviour (related to flood risk) tended to be those who had experienced flooding more than once in the recent past. The repetition of flood events has been linked with increased stress and depression (Hansson et al., 1982) and may therefore act as a stimulant of action. Some interviewees could recall other recent floods, and in the case of one property, had been flooded in 2000 and also another time before that. The interviewee from this latter property had lived in the property for three years prior to interview, but had experienced the flash flood in 2005 and flooding in 2000 which affected the property. Compared with other residents who were interviewed, concern and worry about flooding risks in the future was expressed:

...I've always said the thought of living near a river is wonderful. It is nice when it's nice, but it will be in the back of my mind forever now that it's not so good because of what might happen.

...

Obviously, with what you hear on the news, it is always in the back of your mind now. We went away last weekend, for instance, and you're thinking 'Is it going to rain, is everything going to be alright?' So you start lifting everything up above level.

...

...We've done it (modified their property) because of that and thinking, right, is this what the future holds? Let's try and do something to protect the property.

Repetition of flooding appeared to be a central factor influencing flood risk perception, and therefore response to flooding. Two other individuals who were affected by the 2005 flash flood, but had done nothing to modify their dwellings, stated that experiencing another flood, or a near flood, would lead them to make responses:

What would it take before you decided to do more things to protect this building, what do you think it would take?

I think, probably a near flood again. Or, you know, if one came very near, and then you would think then probably twice about it.

Similarly, another interviewee stated that if the frequency of heavy rainfall increased, and the river rose more frequently, then changes to the house may be considered:

What would it take before you decided to do more to protect the house?

It depends on the weather conditions. If it starts raining heavily, more frequently, and the river starts to come up quite a lot, especially in changing seasons, because it happens more in summer time than it does in winter.

Two other households in Helmsley who were considering making the purchase of several air brick covers and had changed their behaviour to account for flood risk since the 2005 flash flood also displayed an above average concern for future flooding. In the first of these households, while the residents were still debating the purchase of air brick covers, they had some uncertainty about the future flood risk in the area and stated that they were probably going to purchase the covers. The male resident of the property stated:

It (a flood) could happen again. It was once in two hundred and fifty years. Now the Environmental Agency are saying once in a hundred years, but you never know when… 2005 might have been the end of a hundred years. 2009 might be the beginning of the next two hundred years. You don't know when it's going to happen again. You don't know when it's going to happen. It has happened once, so therefore it could happen again.

…

That's one of the air brick covers. They're about seventy-five pounds a time.

That's a lot of money.

It is. We'll end up doing it. If we get the smart bricks, it's a couple of thousand pounds for those, a builder to knock the existing air bricks out and fit them, so it's another thousand there…

The residents of the second household, who had made several adjustments to their behaviour since 2005 to take into account of flooding (including keeping appliances at a higher level, being more observant of river levels and heavy rainfall, and taking their pets indoors after heavy rain), said that they viewed the flood as a one-off event. However one of the residents also stated that flooding was "...always at the back of your mind" when the river was rising, and that "...you can't guarantee" that the flood was a one-off. Therefore, concern and worry about the risk of future flooding, and uncertainty about future flood risk, appeared to be an important factor in encouraging responses to flooding.

As river discharge data is available from the Broadway Foot gauging station in upper Ryedale (Figure 3.2) from the late 1970s to 2009, it was possible to link the perceptions of recent flooding with the peak discharges recorded on the River Rye during this time period (data source: the Environment Agency). Between 1978 and 2009, the 50 highest river discharge peaks recorded at Broadway Foot gauging station in upper Ryedale area (Figure 3.2) are equal to, or above a threshold value of 47.4 $m^3 s^{-1}$. The 2005 flash flood event recorded a peak discharge of 400 $m^3 s^{-1}$ (Wass et al., 2008), and is clearly exceptional in the record as this peak discharge is 284% of the second-largest flow event. Over the whole 1978-2009 period, the pattern of high river discharge events shows a cluster of events from the late 1970s to the late 1980s, as well as from the late 1990s through to the 2000s (Figure 5.6). From the late 1990s to 2009, the magnitude of the highest flow events was particularly extreme. The seven highest discharge peaks recorded at Broadway Foot (1978-2009) occurred in the period 1999-2005 (Table 5.9); furthermore, the period 1998-2008 saw eight of the ten greatest discharge peaks, and twelve of the 15 largest flow events. By contrast, the late 1980s and the majority of the 1990s observed a very low frequency of these high flow events (Figure 5.6), with no (top 50) discharge events at all recorded in the years 1989, 1990, and 1994-7 inclusive.

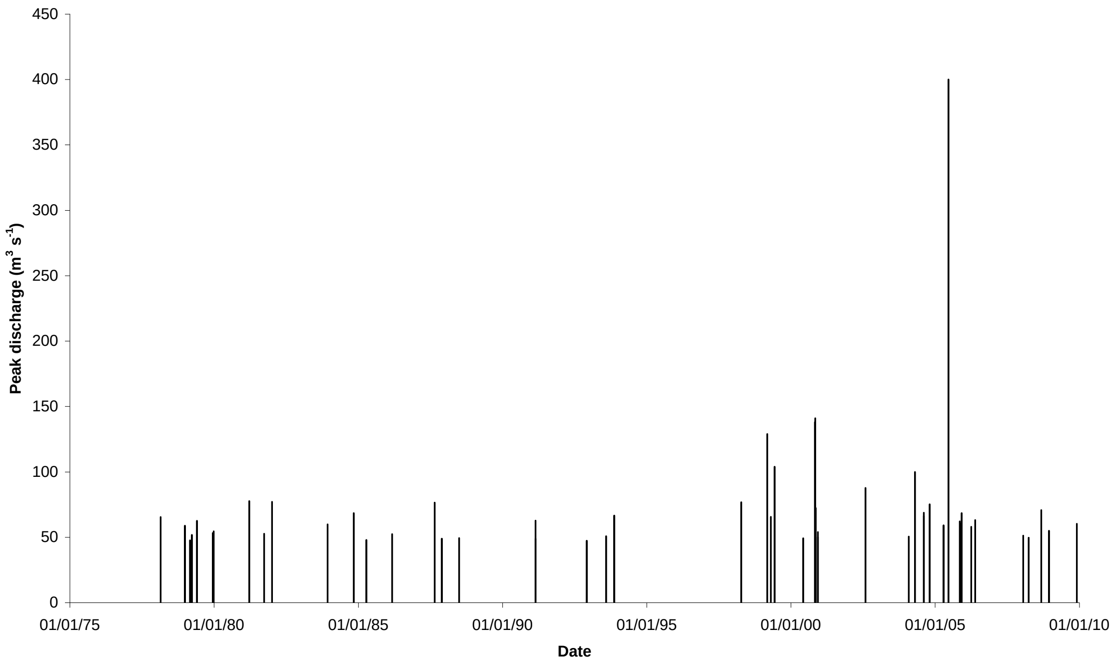


Figure 5.6: The 50 largest river discharge events recorded on the River Rye at Broadway Foot gauging station, 1978-2009. Discharge data provided by the Environment Agency, except 19th June 2005 peak discharge (estimate by Wass et al., 2008).

In addition to the 2005 flash flood event, the years 1999 and 2000 observed particularly large discharge events. In the autumn of 2000, the second highest peak discharge recorded on the River Rye occurred (141 $m^3 s^{-1}$), with an additional peak recorded a few days earlier slightly below this (Table 5.9). Furthermore, the year 1999 also observed the fourth and fifth highest peak discharges on record, with a high of 129 $m^3 s^{-1}$ recorded on the 7th March 1999 (Table 5.9).

Rank	Date	Peak discharge ($m^3 s^{-1}$)
1	19th June 2005	400
2	3rd November 2000	141
3	30th October 2000	138
4	7th March 1999	129
5	8th June 1999	104
6	19th April 2004	100
7	2nd August 2002	87.8
8	22nd March 1981	77.7
9	4th January 1982	77.1
10	11th April 1998	76.8

Table 5.9: The ten largest discharge events recorded at the Broadway Foot gauging station in upper Ryedale, 1978-2009. Discharge data provided by the Environment Agency, except 19th June 2005 peak discharge (estimate by Wass et al., 2008).

Large flow events in 1999 and 2000 correlate well with local knowledge of flooding in upper Ryedale. While knowledge of the 2005 flash flood was unsurprisingly widespread, the flood in the year 2000 was also recalled by some. The years 1999 and 2000 were associated with large flood events in the River Derwent catchment, and Malton, Pickering and Sinnington (Figure 5.1) experienced major flooding in 2000, as did other settlements in the Derwent catchment (Environment Agency, 2007*a*). Across the U.K. as a whole, the widespread flooding in the autumn of 2000 was the most extensive flood event since 1947 (Marsh, 2001). In upper Ryedale, flooding in 2000 was recalled by interviewees living near the River Rye. A female interviewee based in Helmsley recalled flood damages in 2000:

…I was here for the two (floods) that we had – one in 2000, which was quite bad, and then the other one, which was the worst one, in 2005.

Can you tell me a bit about the 2000 one?

If you look out there, it came just up the conservatory.

In total, questionnaire respondents from Helmsley recalled more than one flood in 1999, 2002, 2006 and 2007. One questionnaire respondent recalled the date of the 1999 flood (the 7th March) while another recalled the month of March when the flood took place. Further evidence from interviews with some in Helmsley who lived close to the River Rye suggests an additional event in approximately 2001-2002:

...We've been using sandbags before, on one occasion, but it didn't come nowhere near the house.

When was that?

It would be maybe three or four years previous to that (the 2005 flood). It didn't even come out of the river, you know, it didn't bridge the banks.

Despite the large number of recalled floods by questionnaire respondents since 1998, it is uncertain as to how many of these recalled events were genuine overbank floods of the River Rye, and it seems probable that many of them are (as in 2001-2) simply high river flows which did not cause flooding, or caused very minor flooding. Such high flows and minor floods would have been more readily recalled than those in previous decades. It is also possible that recalled years may be incorrect, due to the limitations of human memory, and refer in fact to floods which occurred in other years. In discovering information about past floods from residents, "...much depends on the clarity of an individual's memory" (McEwen, 1987: 138) and sometimes "...some form of memory is present but (is) attributed to an incorrect time, place or source" (Dodson et al., 2000: 391). The length of time that has passed between the present and events tends to reduce the accuracy of recollections (Malmberg and Blanken, 2006). However, where a resident had experienced, or was aware of, river flooding (in 2000, or in other years), in addition to their experiences of flooding in 2005, they tended to perceive a trend of increasing flooding, and this elevated flood risk perception typically led to them making physical modifications to their houses as a result of greater concern about flooding.

The link between experience of flood events and flood risk perception described above is similar to the association between responses to flooding by the wider population of Helmsley (assessed by questionnaire) and the belief that local floods were getting worse (Sections 5.2.2, 5.2.3). The available data from discharge records, and the characteristics of high flow events on the River Rye over the period 1978-2009 shows that high flows on the River Rye increased in magnitude (of peak discharges) from the 1980-early 1990s to the late 1990s and early 2000s, as a result of extremely large flow events in 1999 and 2000 (Table 5.9). From 1978 to 1998, no flow events were recorded with a peak discharge greater than 100 $m^3 s^{-1}$, but between 1999 and 2005 six such events were recorded. However, aside from the 2005 flash flood, annual mean high flows between 2005 and 2009 were not exceptionally high and have returned to similar levels as experienced in the 1980s (Figure 5.7). It is likely that this is related to a slight decline in rainfall totals over the same period: six out of the seven years between 1998 and 2004 had annual rainfall totals above 1,000 mm, but only one out of five years from 2005 to 2009 recorded greater than that amount. It is also apparent that high flow events on the River Rye have not become faster rising, as the rate of discharge increase during high flow events shows no overall trend between 1978 and 2009 when measured on an annual mean basis (Figure 5.7). The annual frequency of high flows recorded on the Rye is closely related to rainfall patterns: there is a highly significant correlation between the annual frequency of high flow events and annual rainfall totals over the 1978-2009 period (coefficient = 0.52, $p = 0.01$) (Appendix 4). Additionally, the correlation between the frequency of high flow events and number of heavy rain days recorded annually lies just outside statistical significance at the 95% confidence level ($p = 0.08$). As Figure 5.7 shows, there was a clustering of particularly large high flow events recorded between the end of the 1990s and into the 2000s decade, corresponding with an increase in annual rainfall totals and heavy rainfall during the same period of time.

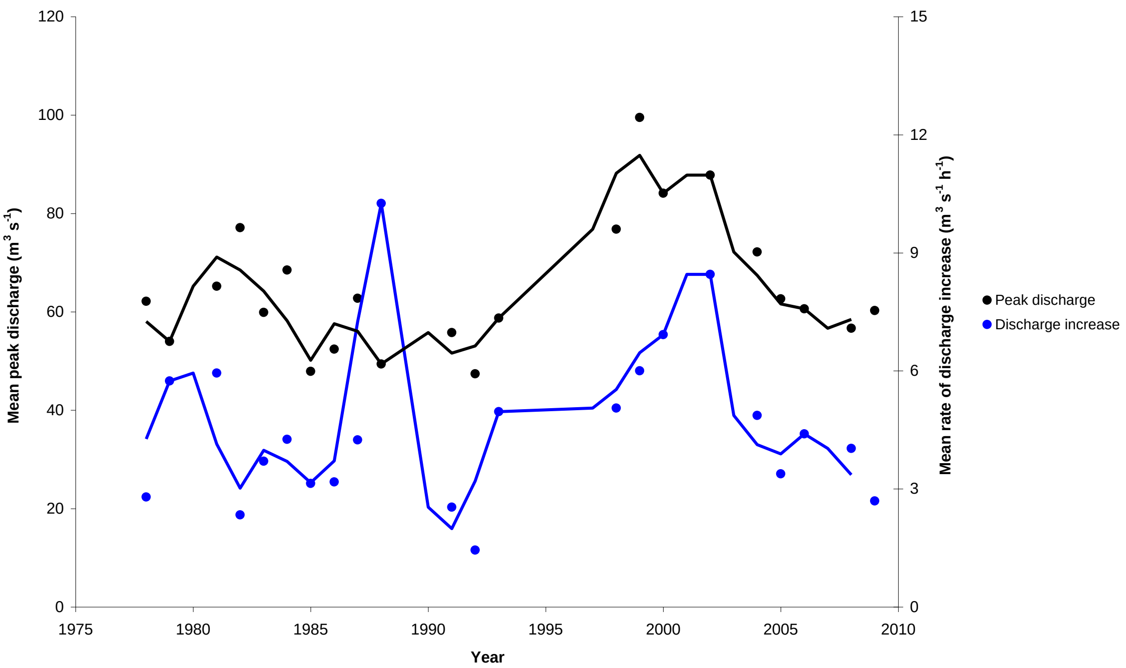


Figure 5.7: Comparison of the characteristics of high flows recorded at Broadway Foot, upper Ryedale, 1978-2009. High flows defined as the 50 largest flow events recorded in the Broadway Foot record (47.4 $m^3 s^{-1}$ and above) with the 19th June 2005 flash flood not included in the data analysis. Figures used are annual means. Lines show two year running averages. Discharge data provided by the Environment Agency.

Therefore, an analysis of physical flow data suggests that, while high flow events and floods were relatively frequent in the upper Ryedale area during the late 1990s and early 2000s, high flow events did not, broadly, become either larger in magnitude or experience higher rates of discharge increase over the period of river discharge monitoring. The rarity of the 2005 flash flood event is therefore further emphasised, and these discharge patterns may have contributed to perceptions among residents that flood risks were not increasing locally. Indeed, the dominant view among most of those who were affected by flooding in 2005 (as well as other interviewees unaffected by the flash flood) was that the flash flood was a one-off event and was unlikely to happen again. The flash flood was described as ‘a freak', 'an Act of God', a ‘tsunami' and the 'flood of all floods' by interviewees. One resident, when asked why they had not done anything to protect his house, explicitly stated that they felt that the flood was a one-off event:

Why have you not done anything?

Because I don't think it's necessary really.

You don't think that a flood is going to happen again?

No.

A comparison of the 19th June 2005 flash flood event with other large flow events shows clearly the exceptional nature of the event (Figure 5.8), both in terms of its peak discharge (400 $m^3 s^{-1}$, or 284% greater than the next largest peak) and the speed of the event's discharge rise. In the flash flood, the River Rye's discharge took one and three-quarter hours to increase from base level, an unprecedented discharge increase based upon available flow data: the average time for a discharge event to rise from the start of the event to the peak was 16.9 hours (based upon the 50 largest discharge events on record). The upper Ryedale catchment clearly responded in an unusual way to the intense rainfall of the 19th June 2005, reinforcing the view of Wass et al. (2008) that the upland Rye catchment behaved extremely unusually to the rainfall event in 2005, in comparison to smaller rainfall events; possibly as the result of the channelling of surface runoff in areas that are not usually active (Wass et al., 2008). The tendency of rivers to behave in unexpected ways during very large events, particularly in upland floods, has been noted (Archer et al., 2007), and statistical estimations of flood rarity are often poorly known in small and/or ungauged catchments (Gaume et al., 2004). Based upon the character of flash flooding in 2005, compared with the available flood discharge record over the late 20th century to present, local residents had some justification in calling the 2005 flash flood a 'one-off', and in turn basing their responses to the flash flood upon this perception.

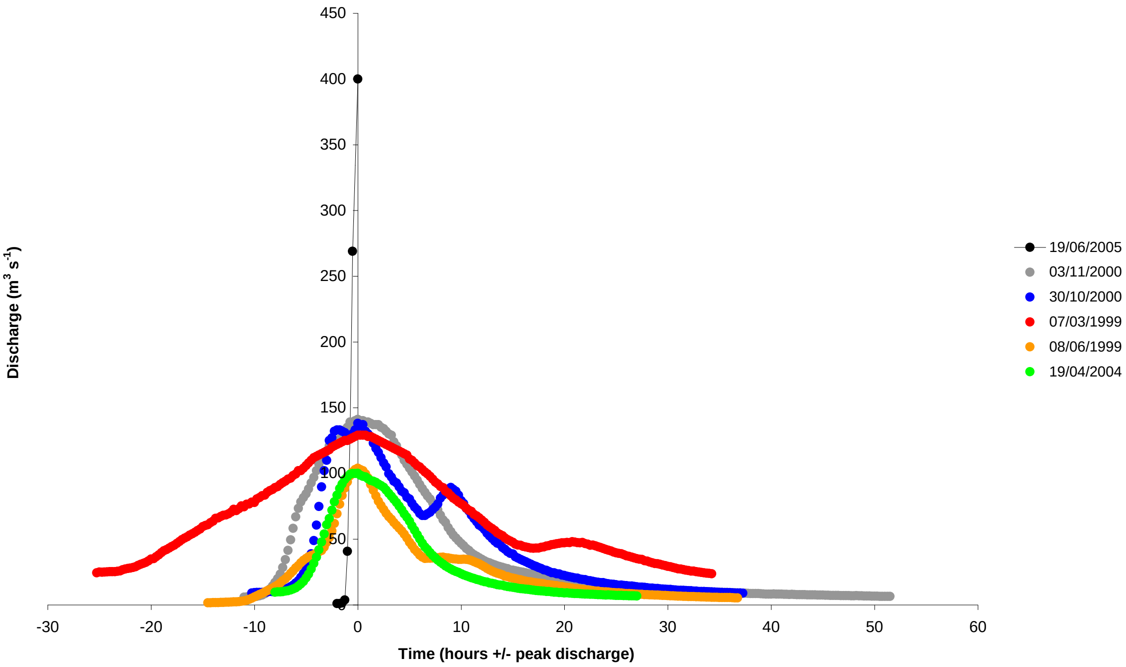


Figure 5.8: Comparison of the six largest discharge events recorded on the River Rye at Broadway Foot, 1978-2009. The flash flood event (19th June 2005) is shown with a black line for clarity. Discharge data provided by the Environment Agency, except 19th June 2005 peak discharge (estimate by Wass et al., 2008).

If a flash flood is defined as a flood which occurs quickly (Collier, 2007) following rainfall, an assessment of high flow events and associated rainfalls suggests that the River Rye is not usually as flashy as it was during the 2005 flash flood, and the runoff response which caused the flood was highly atypical. Rainfall data at 15 minute intervals was provided by the Environment Agency. From the 11th September 2004 (the beginning of 15 minute interval rainfall data availability) to the end of 2009, the mean lag time between the centre of total rainfall and peak discharge (using the method of Bay, 1969) of the 20 largest flow events (n = 17, due to issues with rainfall data for three events) was 7.3 hours. If a further event, which was likely influenced by melting snow, is removed from the calculation (n = 16) the mean lag time is still 7.3 hours. The lag time for the flash flood event in 2005 was a remarkable one hour. Other lag times for available events lay within the range 3.75-14.5 hours: the majority of events record lag times between five and ten hours. Therefore, the vast majority of recent discharge events have shown a moderate response to rainfall. It is likely that this general model of flooding has influenced local perceptions and views, as evidence from interviews shows that the 2005 flash flood was perceived as a one-off, and slow-rise floods were expected in future rather than additional flash floods.

An important influence upon flood risk perception, and therefore response to flooding, was individual understanding of the flood history of the region. Other than the flash flood in 2005, the only other large documented river flood to have occurred in Helmsley and upper Ryedale occurred in 1754 and was recalled by several questionnaire respondents (ten respondents mentioned '1754' the year, with five others offering a less-specific recollection) and commented upon by many interviewees. This is known as the 'Great Flood' which occurred on the River Rye and across the Derwent catchment as a whole. It was a major event, described as "...of a similar magnitude" to the 2005 flash flood (Wass et al., 2008: iii). The history of the Helmsley and Rievaulx area written by McDonnell (1963) makes references to the flood from historical sources, including the washing away of tenancies and damage to Helmsley Bridge (McDonnell, 1963). The flood's strength is shown in a 19th century pamphlet produced by Isaac Cooper, which in turn includes a diary extract describing damage to several houses in Helmsley and serious damage and destruction of bridges in Ryedale.

"October the 28th, 1754:- A great and trable flud of water came by the rever Reye to Helmslay blakeymour, which came with such veamancy that it drove to the ground 8 houses, 5 dwelling houses. Thorten poure creaters wear dround besides a great deal of catel, hey and corn staks. It drove down most part of Helmsla Bredg ... and Revolx bredg down to the ground, and part of Bow bredg and Shacan bredg and abondance of damage in the country besides"

Extract from John Pape's diary (October 28th 1754) in Cooper (1887: 6), cited in McDonnell (1963: 464, Appendix M).

The 1754 flood was therefore very well known locally. The flood constituted an important influence on the flood risk perception of several residents, who suggested that the long time difference (c. 250 years) between the documented major floods to affect Helmsley meant that flood risks in the area were low:

Have you changed your own behaviour to take into account the flood risk? Are you more aware of the flood risk these days?

I suppose I am, but I'm not worried about it. I don't think it will happen again.

Why do you say you don't think it will happen again?

Because it was a one-off. It hadn't happened for two hundred years, so why should it happen in my lifetime?

Any other thoughts about floods?

I'm a bit like (name). It happened 250 years ago, documented somewhere in the local history book, we hope it will be another 250 years plus.

Other residents could recall floods that had occurred in Ryedale, other than the 'Great Flood' and the 2005 flash flood. One questionnaire respondent provided the year 1787, which corresponds to a flood on the Boro Beck, a small stream running from the north of Helmsley (rather than the River Rye) (Figure 5.2): this flood is also recalled by Cooper (1887, quoted in McDonnell, 1963). Similarly, the 1895 flood recalled by one respondent also occurred on the Boro Beck, and a photograph of the flood event, on the 26th July 1895, exists (Figure 5.9). The photograph suggests overbank flooding along the reach of the Boro Beck running alternately underground and in a culvert along the High Street, Church Street and Castlegate areas of Helmsley (Figures 5.2, 5.10).

Figure 5.9: Photograph of a flood on the Boro Beck in Helmsley, July 1895, looking downstream. Photograph used with acknowledgement of Helmsley Town Council and the Helmsley Archive.

Figure 5.10: The Boro Beck in Helmsley under normal flow conditions. This is a view upstream along the stretch which is being flooded in the 1895 photograph (Figure 5.9).

Other recalled floods were more recent. One resident knew about a flood in the 1930s, but stated that this flood had been relatively slow rising and caused by prolonged rainfall. He then stated that he felt that any future floods would also be like this, despite his experience with the 2005 flood, and that he would have time to take action to protect his property. Therefore, the resident had no perception that the flash flood would occur again:

> ... I shouldn't think we'll get another storm like that for a long time.
>
> *So you don't think there's going to be any more major floods in the future then, in this area?*
>
> Well there could be floods in the future but I think... I would have thought a more gentle flood, over a period of time, heavy rain for longer periods and it rises slowly.

The same interviewee made the important additional point that these floods were manageable, and residents were able to respond to the flood, due to the slow rise of the river water:

> …the water back in the years gone by when it did use to flood… back in the 1930s and things… it would just rise very slowly so people would take furniture and move it upstairs, so there was no problem that way.

A flood in the 1930s was mentioned by another interviewee from Helmsley ("...I've seen it up to the middle of the road back in the thirties"), and another resident recalled a flood when he was a child; based on his age, this would place the flood at c. 1928. Three questionnaire respondents suggested that a flood occurred in the 1930-1932 period in Helmsley. Further comments in questionnaires also pointed to a flood occurring at some point in the 1930s:

I remember as a child a very heavy thunderstorm causing flooding in the Ryegate area, but can't remember the date - possibly around 1939/40.

Earlier flood - Mid-1930s - large flood - washed away Ryedale Show stand in Duncombe Park

In 1931 my mother had to be got to hospital in a cart through floods when I was born.

Floods occurred at Malton in the years 1930 and 1931 (Jones, 2000). The review of historical flooding in the Ryedale area by Wass et al. (2008) also provides details of the 1931 flood, which occurred on the 4th September 1931. This historical review quotes newspaper reports (the Yorkshire Gazette) describing serious flooding in Malton. Also, flooding was experienced in Pickering, Sinnington, Marton and Normanby (Wass et al., 2008, Figure 5.11). Details of the precipitation event which caused the 1931 flood are documented in British Rainfall (1931 edition), which describe a major rainfall event associated with "...a deep and complex depression" (Meteorological Office, Air Ministry, 1932: 64) that moved across the U.K. from Ireland. Rainfall on the 4th September 1931 saw rainfall totals greater than one inch (25.4 mm) recorded across a large part of northern England, but with particularly high accumulations (in excess of three inches/76.2 mm) across the North York Moors area (Figure 5.11): the highest rainfall totals for the storm were recorded at stations in the central North York Moors, including Castleton (127.3 mm), Kildale Hall (126.2 mm) and Danby (112.5 mm) (Meteorological Office, Air Ministry, 1932) (Figure 5.11). British Rainfall also lists a comparison between floods in 1931 and 1930, providing a comment by Mr. R.H. Rastall of Whitby, who described the floods of the 4th September 1931 and 20th-23rd July 1930 as "...almost precisely similar" (Meteorological Office, Air Ministry, 1932: 65). There was a flood on the River Derwent; also at Grosmont on the River Esk (Figure 5.11), a river level rise of 21 ft (6.4 m) in a day was described by Mr. Rastall (Meteorological Office, Air Ministry, 1932: 66). Clearly large floods associated with heavy rainfall events occurred across North Yorkshire in the early 1930s, and memories of flooding in the early 1930s were also found in upper Ryedale.

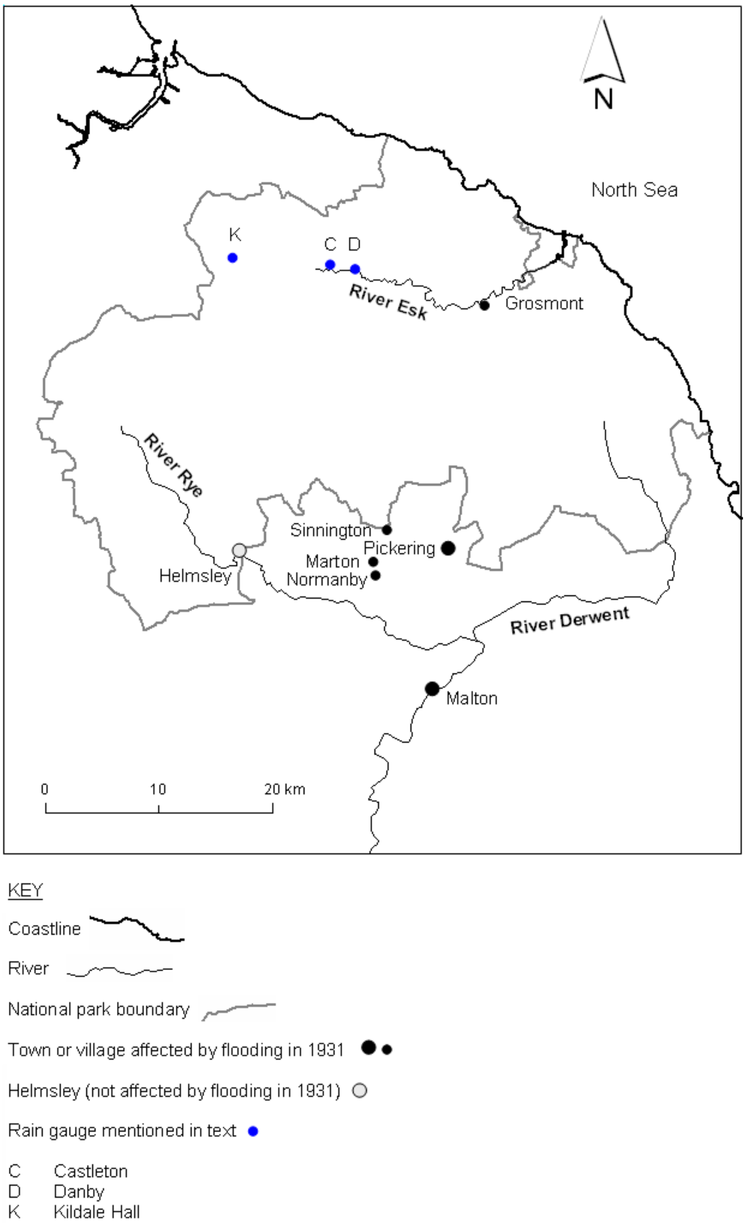


Figure 5.11: Areas in and around the North York Moors National Park affected by flooding in 1931. Diagram contains Ordnance Survey Strategi® data: © Crown Copyright/database right 2011. An Ordnance Survey/EDINA supplied service.

The year 1947 was mentioned as containing a flood event in questionnaires, linking to a major documented flood in this year. In 1947, widespread, extreme flooding occurred across England and Wales, due to a prolonged, cold and snowy winter being followed by a mild period which brought heavy rainfall and snowmelt in March (Risk Management Solutions, 2007): the flood extent totalled c. 700,000 acres (Risk Management Solutions, 2007). The 1947 flood is an example of a snowmelt- (or snowmelt and rainfall-) driven flood, with other such events occurring in 1963 and 1982 in the British Isles (Ferguson, 1984). A 79 year old resident of Helmsley clearly recalled, in an interview, the snowmelt-driven nature of the flood:

> Before it was always when the snow melted, that's when we got them (floods)... The snow was freezing on my glasses. It was terrible. That's when we had that bad flood in 1947 when the snow melted.

Therefore, the use of local knowledge enabled a number of floods, unrecorded by modern hydrological monitoring, to be identified. Additionally, the larger River Derwent catchment has a long history of flood events from the start of the 20th century to the 2000s decade (Environment Agency, 2007*a*). A study of high flow events shows a clear contrast between events in the catchment uplands and elevated discharges on the main River Derwent, consistent with known differences between upland flash floods and lowland floods (e.g. Bronstert et al., 2002). Comparisons of the flood regime of upper Ryedale with the neighbouring River Seven catchment (gauged at Normanby, Figure 3.2) and the lowland River Derwent (discharge data available from the A64 road bridge station, Figure 3.2) shows, firstly, the much greater flashiness of high flow events recorded at the upland gauging stations. A comparison of peak discharges and the rate of discharge rises among the two upland gauging stations and the Malton station showed that discharges at the upland stations tended to rise much quicker, and have larger peak discharges, than high flow events at Malton (Figure 5.12). On average, the largest 20 flow events recorded on the River Rye had a peak discharge of 44 times the long-term mean flow, with a respective figure of 66 times the mean flow for high flow events on the River Seven. However, at

Malton, the peak discharges of the highest ten flow events recorded were on average only 5.3 times the mean flow. In terms of the magnitude of discharge rise experienced during high flow events (expressed as multiples of the mean flow, per hour), if the 40 Rye and Seven events are grouped together, the average rate of discharge rise for the upland events is 104 times the average rate for the River Derwent at Malton (61 times if the 2005 flash flood event in upper Ryedale is not included in the calculation). Additionally, the average time for high flow events to peak from the start of the event was 17.6 hours at Broadway Foot on the River Rye (18.6 hours, not including the flash flood event in 2005) and 19.7 hours on the River Seven. However, due to the much larger catchment area of the River Derwent at Malton (1,360.1 km^2 (Environment Agency, 2011*a*), which includes the upper Rye and Seven catchments) in comparison to the two upland catchments (131.7 km^2 and 121.6 km^2, respectively (Centre for Ecology and Hydrology, 2011*a*,*b*)) (Table 3.9), the mean time for discharge rise at Malton was 99.2 hours, or over five times longer than high flow events take to peak, on average, in the upland catchments. Therefore, while flood events occurring downstream of the River Rye may affect a larger number of properties and people than upstream events such as the 2005 flash flood, the upland high flow events were flashier in nature and therefore more dangerous if they caused flooding, due to known difficulties faced in responding and mitigating towards such events (e.g. Gruntfest and Handmer, 2001). Additionally, the nature of upland high flows/flooding was more severe in the neighbouring River Seven catchment, based upon peak discharges and the rate of flow increase between the Seven and Rye catchments (Figure 5.12).

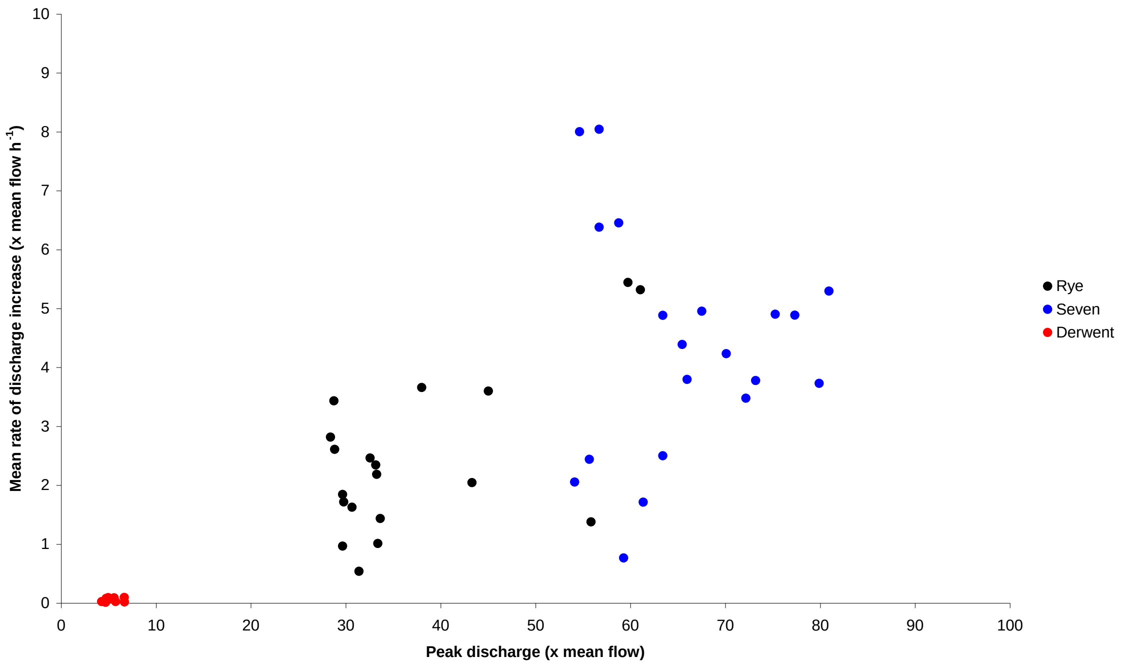


Figure 5.12: The characteristics of the 20 largest flow events recorded on the upland River Rye (at Broadway Foot) and River Seven (at Normanby) catchments between 1978 and 2009, and the ten largest flow events recorded on the River Derwent (at Malton) between 2003 and 2009. Not all events are shown, however all Malton events are shown. Discharge data provided by the Environment Agency.

Although high flows in the upland catchments appeared to be potentially more dangerous than those in lowland areas, there is a clear difference between the frequency of flood events in Helmsley and upper Ryedale, and flood histories of the wider River Derwent catchment, including Malton, Pickering and Sinnington (Figure 5.1). The Catchment Flood Management Plan for the River Derwent lists eight floods which have occurred in the wider Derwent catchment between 1927 and 2000, with the 2000 event being the worst flood on record (Environment Agency, 2007*a*). The Ryedale Flood Research Group noted the occurrence of six floods (at the time of research) that had occurred in Pickering between 1993 and 2007, as well as photographic evidence of historical floods in 1930, 1932 and in the 1960s (Ryedale Flood Research Group, 2008*b*). Roads and homes were also flooded in Pickering in 2008 (British Broadcasting Corporation News, 2008). In Sinnington, the Ryedale Flood Research Group identified eight floods which occurred in the period from 1880 to 1951, and showed photographic evidence of floods in 2002 and 2008, in addition to the flood in 2007 (Ryedale Flood Research Group, 2008*c*). By comparison, flooding in Helmsley has not occurred as frequently, except for the 2005 flash flood event and relatively minor overbank flooding in 1999 and 2000; the latter affected a much smaller area than in 2005, and a substantially lower number of homes (Section 5.3.1.1). In comparison with the main River Derwent, and Pickering and Sinnington, Helmsley and upper Ryedale have not experienced a high recent frequency of floods. The contrasting nature of these flood records was an important influence on hazard perception, as it was frequently mentioned by interviewees (supported by questionnaire data) that flood risks were much worse in other areas of the region. This viewpoint therefore tended to reduce the perception of local flood risks. When asked about the perceived likelihood of flooding in the next ten years at a number of locations, questionnaire respondents were far more likely to perceive a high flood risk in York and Pickering (Figure 5.1) than in upper Ryedale or at their own house (Table 5.10). Approximately one-in-ten of all respondents stated that the risk of future flooding in upper Ryedale was 'high', compared with just over 60% of respondents who rated flood risks in Pickering as high (Table 5.10).

	Low	Medium	High	N
Perceived likelihood of flood in upper Ryedale in the next 10 years	52.8	37.5	9.7	144
Perceived likelihood of flood in own house in next 10 years	98.6	0.7	0.7	142
Perceived likelihood of flood in Pickering in next 10 years	2.2	35	62.8	137
Perceived likelihood of flood in Central York in next 10 years	4.4	16.8	78.8	137

Table 5.10: Perceptions of the probability of future flooding among questionnaire respondents. Low, Medium and High figures are percentages.

A further belief stated by several interviewees was that the local climate was becoming wetter, with an increase in heavy rainfall, particularly in summer; however some interviewees failed to make a link between increased heavy rainfall and a recurrence of the 2005 flash flood, or an increase in future flood risk generally. As an example, one interviewee showed uncertainty as to the links between increases in heavy rainfall and flood risk:

> ...I know we're getting more adverse weather, we're having flash storms and this sort of thing, like, there were in the South, erm, but I don't think here... we're going... I shouldn't think we'll get another storm like that for a long time.
>
> ...
>
> *Are you at all concerned about the possibility of flooding in the future?*
>
> No, not really that concerned. It doesn't really worry me that much, they always say you know, lightning doesn't strike in the same place twice, but it does... Erm, I don' really know, I wouldn't like to say... anything can happen with nature. And the thing is now we do seem to be getting more and more localised storms, erm, and flooding and things like this really.

By contrast, two other residents appeared to link increased rainfall (particularly in summer) to more frequent flooding nationally:

> We think things are changing generally. It's getting a lot wetter. We're not getting good summers. There is more flooding. There has been a spate of it throughout Britain, hasn't there?

> ...One (problem) is we're getting heavy downpours of rainfall, particularly in the summer.
>
> *Is this in this area?*
>
> I get the feeling it's all over. The flood they had in Devon a couple of years ago, Hull, Sheffield, Gloucester last year, that was just heavy precipitation in the summer.

Similarly, some interviewees (unaffected by flash flooding in 2005) argued that there was a possible link between a perceived increase in heavy summer rainfall and increasing local flood risk:

Do you think it is likely that the area will experience more big floods in the future?

Well if we have these heavy concentrated rainstorms it's always possible. Particularly if it happens over the summer, where the water washes straight off the surface and into the river courses. It could happen, but I think it will very much depend on where the rain is, it could be a bit of a Boscastle situation, which is what we got last time?

The identification of summer as a period of particularly high flood risks, by these residents, was supported by river discharge records. Firstly, over the 1978-2009 period, the largest 50 discharge events were distributed fairly evenly between the seasons, though with a slight bias towards winter and spring (Table 5.11). However, the most extreme high flow events did not occur in winter. Although winter events constituted 30% of the 50 highest events, this proportion drops to 16% for the top 25 flows, and just one out of ten of the highest discharge events occurred in winter (Table 5.11). By contrast, the largest discharge events tended to occur in spring (four of the ten wettest events), summer (three of the ten wettest events) and autumn (just below a third of the wettest 25 events). However, the difference in proportions between spring, summer and autumn appears relatively small (Table 5.11). While the 2005 flash flood was by far the largest recorded discharge event in upper Ryedale, very large discharge peaks in the very wet autumn of 2000 were the second and third largest flow events, and two events in 1999 (in spring and summer) were the fourth and fifth largest flows on record (Table 5.9). A tendency for the highest winter flows to be less extreme than those in other seasons was also confimed by the discharge record: the largest winter discharge event was merely the ninth greatest recorded peak (Table 5.9). Furthermore, spring, summer and autumn all recorded two discharge events in excess of 100 m^3 s^{-1}, while the winter discharge peak was notably lower at 77.1 cumecs.

This pattern of frequent, but relatively moderate winter high flows and minor floods, with higher flood risks in summer, was reflected upon by several interviewees. As an example, a resident from Helmsley stated that "...townies think the (flood) dangers come in the winter, but they don't", showing an understanding that flood risks are highest in summer.

Season	50 highest events	25 highest events	10 highest events
Winter	15 (30%)	4 (16%)	1 (10%)
Spring	14 (28%)	7 (28%)	4 (40%)
Summer	9 (18%)	6 (24%)	3 (30%)
Autumn	12 (24%)	8 (32%)	2 (20%)

Table 5.11: The seasonal distribution of the 50, 25 and ten highest discharge events on record in upper Ryedale (at Broadway Foot), 1978-2009. Discharge data provided by the Environment Agency, except 19th June 2005 peak discharge (estimate by Wass et al., 2008).

In addition to peak discharges, high flow events were also assessed in terms of the rate of discharge rise. The mean rate of discharge increase recorded during the largest 50 flow events recorded in upper Ryedale, along with the peak discharges, is shown in Figure 5.13. High flows in winter tended to be less extreme (in terms of peak discharge, and the rate of discharge increase) than those recorded in other seasons (Figure 5.13). The season that records high flows with the highest average peak discharges was autumn, if the 2005 flash flood event is removed from the summer mean. The seasonal centroids shown on Figure 5.13 show that the peak discharges of autumn high flow events tended to be larger than those in other seasons: the mean peak discharge for the autumn events was 76.4 m^3 s^{-1}, and summer (not including the 2005 flash flood) and spring both recorded similar averages, (69.1 and 67.3 m^3 s^{-1}, respectively). Winter high flow events had a much lower mean peak discharge of just over 57 m^3 s^{-1}. Meanwhile, high flow events tended to rise fastest in summer (Figure 5.13). The mean rate of discharge increase in summer (not including the 2005 flash flood) was 6.7 $m^3 s^{-1} h^{-1}$: a higher rate than in other seasons, notably so in comparison to winter high flows (3.1 $m^3 s^{-1} h^{-1}$).

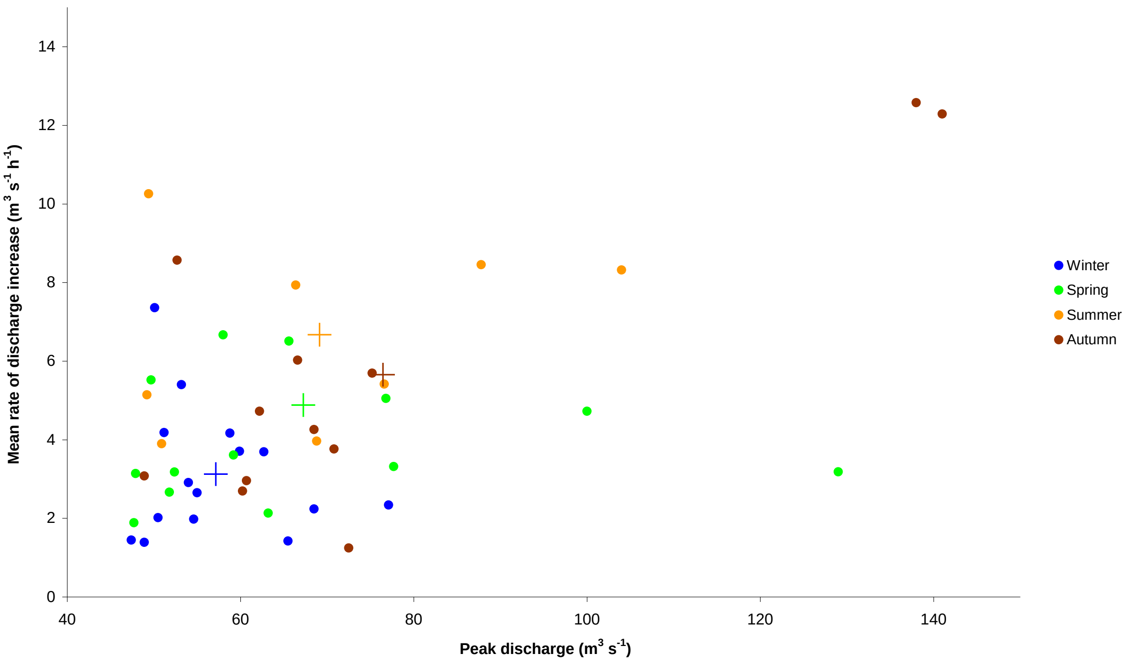


Figure 5.13: The peak discharges and mean rates of discharge increase for the 50 largest flow events recorded at Broadway Foot, upper Ryedale, 1978-2009. Events are categorised by the season in which they occurred. The mean centroids for each season are shown by cross marks (+) on the graph. The summer mean centroid does not take into account of the 2005 flash flood. Not all events are shown on the graph, including the 2005 flash flood. Discharge data provided by the Environment Agency.

Responses to flash flooding among residents were therefore influenced by a number of factors. Although hazard perception, and anticipating uncertainty about the risk of future flooding (and the difficulty in visualising the probability of a future flash flood) were important factors influencing responses to flash flooding among residents in upper Ryedale, other factors limited household responses to the flash flood. For example, two directly affected residents did not own their houses, and therefore did not feel compelled to spend money on changes to the building:

> I'm only a tenant, you see, so I'm not going to spend a lot of my money. I don't have a lot. I am not going to spend a lot of money to protect the property, as such, because it isn't mine.

In a sense, if it was my house I would probably spend more money in doing the protection, because it's yours, with it not being mine, I am still capable of doing it and I still could do it, but it would be on more of a limited scale.

Another interviewee stated that he had wanted to purchase flood doors. He had tried to get his insurance company to pay for flood doors, but they had refused:

...There's nothing we can do apart from put flood doors on. I did ask the insurance company to pay for them, but they wouldn't.

Did they give you a reason?

They just said no. I said 'If you get a couple of doors on that are going to cost three or four hundred a piece, it's going to save you a lot of money in the long run'.

Two more residents also had looked into purchasing door and window covers. However they felt that installing the flood doors may encourage crime, as well as being very expensive to purchase in their own right:

If you put this on the front door, somebody knows you're away. 'Burglars, please come in.' You're caught. We've got a notice on the garage wall saying 'Please don't leave any deliveries.' When we came back from holiday in June, there had been a parcel left there for a fortnight. This was before we put the notice there. If something doesn't say to burglars… There are bad lads about. This is why we've… We had a burglary just before Christmas. This is why we put the… There's a cost. That was over two thousand pounds to put up gates on both sides, so there is a cost to these things.

Personal attitudes such as these have been found in other studies: following urban flooding in Manchester in 2004, some interviewees who did not mitigate against future flooding mentioned the risk of crime, and also financial reasons (Douglas et al., 2010). Similarly, the relative concern over flood damage and personal vulnerability to flooding, in contrast to other natural/human hazards, has been shown to be an important variable linked to the purchase of flood insurance (Blanchard-Boehm et al., 2001). For instance, one interviewee who was heavily affected by the flash flood in 2005 gave a number of issues which affected himself and his business (including the threat of rural crime, poor public services, a lack of community spirit as well as planning issues with the National Park Authority) which were unrelated to flooding. The resident had an attitude that there were more important issues affecting him in his day-to-day life than flooding. In some interviews in Helmsley, residents mentioned that they enjoyed living near a river. Three residents surveyed mentioned that they did not want to let worrying about flooding take over their life. One comment made gave an example of this attitude:

I'm not going to lose any sleep over it. Basically, you've just got to carry on with your life. If you bother yourself that much about it, you know, you'll send yourself loopy.

The perception that flood risk does not constitute a major factor in day-to-day life, or is otherwise underestimated, has also been found by other participatory research following flooding (Burningham et al., 2008; Botzen et al., 2009). In the words of Kates (1962), "Flood hazard, even when perceived, is but one of a host of problems requiring solution, and... is quickly submerged beneath the requirements of paying the rent or hiring help" (Kates, 1962: 124). Research in England has suggested that residents prefer to think of their homes as places that are safe, and therefore even if at risk of flooding they dislike trying to defend them due to the increase in concern about the safety of their property, and do not want to bring in protective measures as a result (Harries, 2008).

5.3.3 Differences between questionnaire and interview responses

An analysis of questionnaire data from a larger sample of Helmsley residents (Table 5.12) suggested some contrasts with the responses of interviewees, related to the perception of flood risk. For instance, a majority of questionnaire respondents disagreed with the statement that the 2005 flood was a one-off event and would not happen again (n = 152), which contrasted with the opinions of many of those directly affected by the flooding. However, questionnaire respondents did not perceive an increasing trend in (fluvial) flooding in the area, as pluralities of respondents that were asked if flooding from the River Rye or other streams in Ryedale was/were getting worse replied that they neither agreed, nor disagreed (n = 148). Despite this, 47% of respondents felt that flooding in Ryedale would occur more frequently in the future (n = 151). Meanwhile an overwhelming majority (nearly nine in ten) of respondents agreed that flooding was getting worse across the country (n = 148). When asked about the perceived likelihood of flooding in the next ten years at a number of locations, questionnaire respondents were far more likely to perceive a high flood risk in York and Pickering than in upper Ryedale or at their own house. 79% of respondents believed that the likelihood of a flood in central York over the next ten years was high, and 63% of respondents felt the same about a flood in Pickering (n = 137). Meanwhile, only 10% of respondents felt that there was a high likelihood of a flood in Upper Ryedale within ten years and an additional 38% rated the risk as medium (n = 144). Perceived flood risk at questionnaire respondents' own houses was minimal, as 98.6% of respondents rated the risk of a future flood there as low (n = 142). This perception of a greater flood risk at other locations, compared with upper Ryedale, was also found in interview responses.

	Disagree	N.A.N.D.	Agree	N
The flood which occurred in Ryedale in June 2005 was a one-off event and will not happen again	52.6	22.4	25	152
Flooding in Ryedale will occur more frequently in the future	14.6	38.4	47	151
Flooding of the River Rye is getting worse	28.4	38.5	33.1	148
Flooding from other streams in Ryedale is getting worse	18.9	44.6	36.5	148
Surface water flooding in Ryedale is getting worse	10.2	29.3	60.5	147
Across the country as a whole, flooding is getting worse	4.1	8.8	87.2	148

Table 5.12: Flood risk perception of questionnaire respondents: views of the 2005 flash flood and flooding trends. 'N.A.N.D.' stands for 'Neither agree nor disagree'. Disagree, N.A.N.D. and Agree figures are percentages.

5.4 Assessment of links between river discharge and rainfall: a 'pseudo flood' series

The aim of this section of the thesis is to examine the relationships between discharge and rainfall for the largest discharge events on record in the upper Ryedale catchment, as recorded on the River Rye at Broadway Foot gauging station. In doing so, the potential for generating a 'pseudo flood' series from longer-term rainfall records will be critically evaluated. Gauging station records from upland areas are short (McEwen, 1987; Macklin and Rumsby, 2007), and there may be value in assessing links between river flow events and the much longer constructed rainfall record (lasting 94 years in the case of upper Ryedale). The central component of the following analysis is an assessment of the 50 largest discharge events on record at Broadway Foot (recorded from 1978 to 2009, with peak discharges varying between 47.4-400 $m^3\ s^{-1}$). Firstly, this section describes the methods used in the analysis of the discharge series (Section 5.4.1), prior to assessing the results of the analysis for the largest discharge events and rainfall (Section 5.4.2) and a second analysis of the largest discharge events recorded during a period where higher resolution 15 minute duration rainfall data was available (Section 5.4.3). Following this is a section discussing the completed, longer-term flood record and its links to other findings of the thesis, including the rainfall analysis in Chapter 4 and the findings of this chapter (Section 5.4.4).

5.4.1 Description of methods

Prior to the analysis of the 50 largest discharge events, an analysis of the relationships between discharge and sub-daily rainfall events was undertaken. For the period of 11th September 2004 to the end of 2009, 15 minute resolution rainfall data is available alongside 15 minute discharge data (Section 3.7.1). This dataset was used to assess relationships between peak discharge and total event rainfall, lag time, rainfall event duration and the peak rainfall rate (the maximum 15 minute rainfall intensity recorded). Although 20 discharge events were identified, only 16 events were included within these calculations. No rainfall was recorded at one event, at another event 15 minute rainfall data was flagged as suspect, and at another event the causative rainfall event was highly uncertain and returned an abnormally long lag time. The fourth of these events was assessed to be affected by snowmelt and was also discounted.

To select the specific daily rainfall value to compare to the corresponding peak discharge, two distinct methods were used to produce separate values for each event. The first method involved applying a lag time to the time of the peak discharge. This lag time was the mean lag time of the 16 largest discharge events described above (7 hours, 20 minutes). This was subtracted from the time of the peak discharge to identify the estimated timing of rainfall. The key daily rainfall value (daily rainfall running from 9 am to 9 am, the standard time when rain gauges are read) was therefore identified.

A second method was also used to assess causative rainfall events. After a preliminary analysis, it was clear that some discharge events had occurred following more than one day of high rainfall. Therefore, a ‘multi-day rainfall’ value was produced where appropriate, summed over an extended number of rain days. This value was a sum of the rainfall on the day (9 am to 9 am period) when the flow event’s peak discharge occurred, and the day (as defined above) when the start of the discharge event occurred, and (infrequently) the rainfall on any additional days in between.

As this piece of research assesses the relationship between discharge events and rainfall, an attempt was made to remove discharge events where snowmelt (a contributing factor to floods from upland areas (Ferguson, 1984)) is a potential factor influencing runoff. Snow depth data for the period of discharge monitoring (1978 to 2009) was retrieved from the MIDAS Land Surface Stations database (National Centre for Atmospheric Science, British Atmospheric Data Centre, 2006) at two stations: the lowland station of Leeming (33 m altitude, c. 31 km from Helmsley) and Fylingdales (262 m altitude, c. 29 km from Helmsley) (Figure 5.14). The Leeming record was most complete and covered the 1978-2009 period, while the Fylingdales record ran from 1984 and had a considerable amount of missing data. The depth of snowfall and the timing of its reduction were assessed where snowfall was recorded prior to high river discharges. Six of the 50 discharge events were assessed as being potentially influenced by snowmelt and were therefore removed from the analysis. Two further discharge events with negligible associated rainfall (0.1, 0.6 mm daily rainfalls as assessed by the lag method, less than 1.8 mm ‘multi-day’ rainfall) were also removed, leaving 42 events.

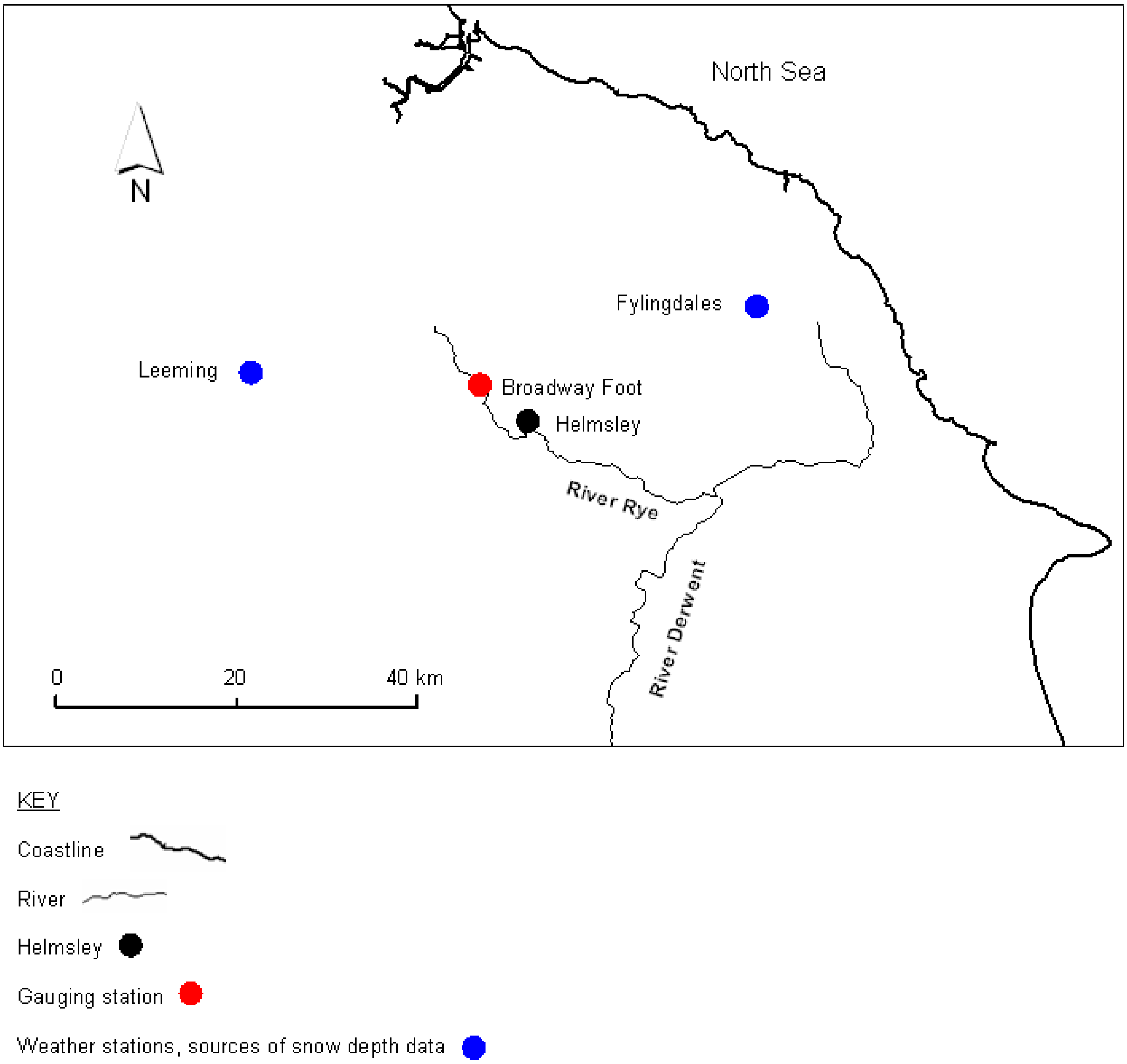


Figure 5.14: Sources of snow depth data: Leeming and Fylingdales, also showing Broadway Foot gauging station and Helmsley. Diagram contains Ordnance Survey Strategi® data: © Crown Copyright/database right 2012. An Ordnance Survey/EDINA supplied service.

In order to assess the possible bias of the extreme 2005 flash flood event (peak discharge = 400 m^3 s^1 (Wass et al., 2008)) upon the discharge-rainfall relationship, three different samples of discharge events are analysed: the full series of 42 eligible events, all events minus the 2005 flash flood event (n = 41), and all events except estimated overbank floods (n = 38). Overbank floods occurred in 2005 (the flash flood, 19th June), 2000 (peaks of 141 and 138 m^3 s^{-1} on the 3rd November and 30th October respectively) and 1999 (7th

March, 129 $m^3 s^{-1}$). These four floods were recalled directly by interviewees and questionnaire respondents, and these peak flows are all in excess of the bankfull flow of the River Rye at Broadway Foot (approximately 122.9 $m^3 s^{-1}$: contains Environment Agency information © Environment Agency and database right).

5.4.2 Analysis of high river flow events and daily rainfall records

The r^2 value (the correlation coefficient, squared) represents "…the percentage of variance in one variable that is predicted or explained by the other" (Ozer, 1985: 307). The r^2 values for the relationships between peak discharge and rainfall variables are shown in Table 5.13 below, with graphical representations of these relationships shown in Figures 5.15 and 5.16. The largest r^2 value recorded for the single day (lag) rainfall value is 0.235 for all 42 events (Table 5.13, Figure 5.15). However, the 2005 flood presents an outlier that exerts a great leverage in any linear model fitted and violates one of the underlying assumptions of linear regression analysis, that the distribution of the errors is approximately normal (White and Macdonald, 1980). In this case, removing the 2005 flash flood event from the linear regression calculation reduces the r^2 value. Where potential multi-day rainfall events are included, the r^2 values decline in two of the three models, except for when the 2005 flash flood is removed: the value of 0.267 here is the highest r^2 value of any calculation with this dataset (Table 5.13, Figure 5.16). This regression is highly statistically significant ($p = 0.0005$), and Equation 5.1 detailed below has been derived from this data.

Peak discharge (m^3 s^{-1})	Rainfall (mm) [Lag method]	Rainfall (mm) [Multi-day rainfall method]
All events (n = 42)	0.235 (0.0011)	0.18 (0.0051)
All events except 2005 flash flood (n = 41)	0.163 (0.0090)	0.267 (0.0005)[1]
All events except estimated overbank floods (n = 38)	0.143 (0.0193)	*0.076 (0.0940)*

Table 5.13: r^2 values and linear regression between peak discharge and rainfall values for the largest discharge events recorded on the River Rye at Broadway Foot, 1978-2009. p-values are shown in brackets (values in italics are not statistically significant at the 95% confidence level). Further information on statistically significant relationships is included within Appendix 4. [1] – the equation for this relationship, derived from the data is specified below (Equation 5.1). Discharge data provided by the Environment Agency, except 19th June 2005 peak discharge (estimate by Wass et al., 2008), rainfall data formed from data contained in the Met Office MIDAS database.

$$R^{md} = 10.52 + 0.42Q$$

where R^{md} = rainfall (multi-day, mm) and Q = peak discharge (m^3 s^{-1}).

Equation 5.1: Linear regression between multi-day rainfall and peak discharge, sample n = 41. Further details of this regression are included within this Section (5.4.2).

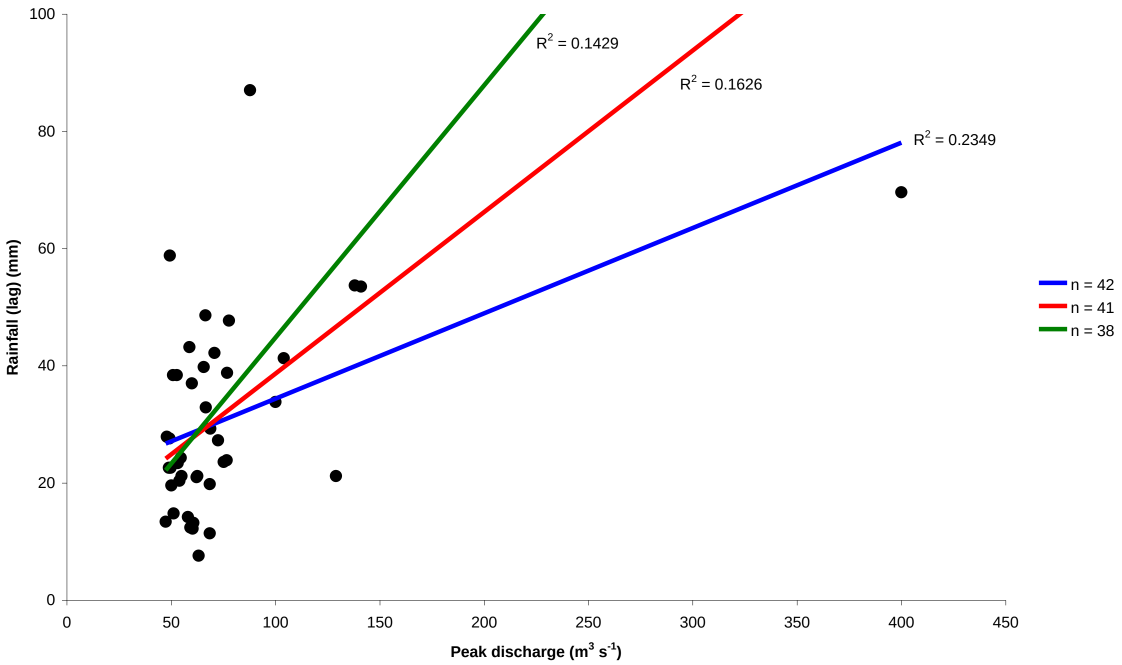


Figure 5.15: Relationships between peak discharge and rainfall for the largest flow events recorded at Broadway Foot, 1978-2009. Rainfall data formed from data contained in the Met Office MIDAS database, discharge data provided by the Environment Agency except 19th June 2005 peak discharge (estimate by Wass et al., 2008).

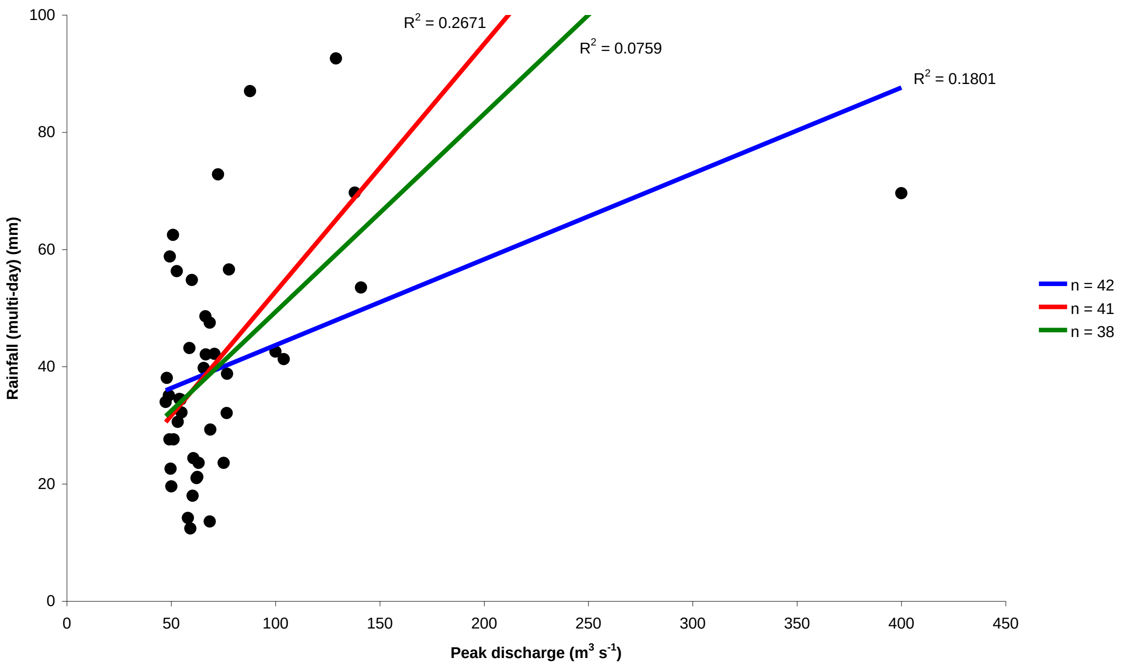


Figure 5.16: Relationships between peak discharge and multi-day rainfall for the largest flow events recorded at Broadway Foot, 1978-2009. Rainfall data formed from data contained in the Met Office MIDAS database, discharge data provided by the Environment Agency except 19th June 2005 peak discharge (estimate by Wass et al., 2008).

5.4.3 Relationships between peak discharge and sub-daily rainfall events

An analysis of the largest discharge events recorded between 11th September 2004 and the end of 2009, and characteristics of associated rainfall (Table 5.14) shows that r^2 values vary considerably if the 2005 flash flood event is removed from the linear model. For instance, when total event rainfall (assessed at the 15 minute level) is considered, when the 2005 flash flood is included there is an r^2 value of 0.538 which reduces to 0.044 when the 2005 flash flood event is removed (Table 5.14). When displayed graphically, the 2005 flash flood is clearly an outlier which causes the regression trendline to reverse direction (Figure 5.17): this short rainfall record contains few very large discharge and rainfall values. Similarly, when peak discharge is compared with peak rainfall rate, removing the flash flood event from the calculation causes the strong r^2 value to reduce dramatically. When the intensity of these rainfall events is also assessed, the exceptional intensity of the 2005 flash flood event rainfall, compared with other rainfall events, is clear (Figure 5.18). There is no obvious trend between rainfall intensity and event rainfall total among other events. Therefore, the data does not support the use of a linear model to construct predictive relationships between discharge and rainfall, even when fine resolution (15 minute) data is available.

	Peak discharge comparison, all rainfall values (n = 16)	Peak discharge comparison, all rainfall values except 2005 flash flood (n = 15)
Lag time (mins)	*0.195 (0.0866)*	*0.038 (0.4882)*
Total event rainfall (mm)	0.538 (0.0012)	*0.044 (0.4505)*
Peak rainfall rate (mm, 15 mins)	0.944 (0.0000)	*0.002 (0.9864)*
Rainfall event duration (hours)	*0.22 (0.0671)*	*0.123 (0.2006)*

Table 5.14: r^2 values, linear regression between peak discharge and rainfall values, largest discharge events recorded on the River Rye at Broadway Foot, 11th September 2004 - 2009. p-values are shown in brackets (values in italics are not statistically significant at the 95% confidence level). Further information on statistically significant relationships included within Appendix 4. Discharge data and rainfall data provided by the Environment Agency except 19th June 2005 peak discharge (estimate by Wass et al., 2008).

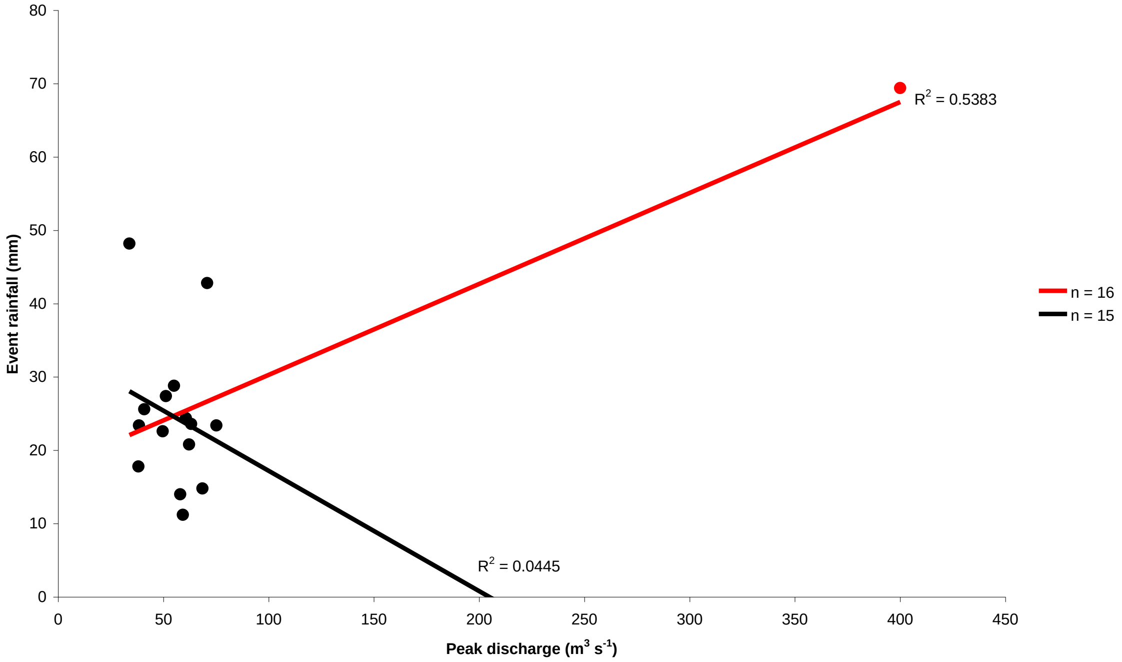


Figure 5.17: Relationships between peak discharge and total event rainfall (assessed by 15 minute resolution data), River Rye, 11th September 2004 – 2009. Red trendline shows full dataset (n = 16), black trendline shows dataset excluding the 2005 flash flood event (n = 15). The flash flood in 2005 is shown as a red dot. Discharge data and rainfall data provided by the Environment Agency except 19th June 2005 peak discharge (estimate by Wass et al., 2008).

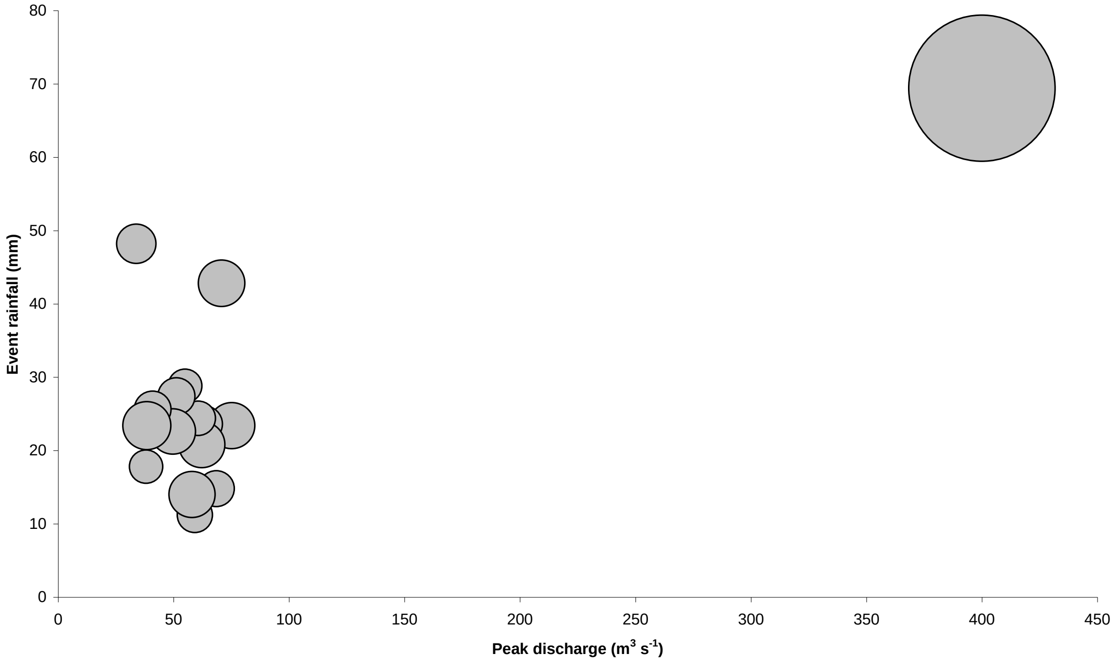


Figure 5.18: The same data as shown in Figure 5.17. Bubble size is proportional to the rainfall event intensity (mm h^{-1}). Discharge data and rainfall data provided by the Environment Agency except 19th June 2005 peak discharge (estimate by Wass et al., 2008).

5.4.4 Reconstructed possible overbank floods

The linear relationships between the largest runoff events and daily rainfalls are generally weak and are characterised by r^2 values that are relatively low. If all eligible flow events are included in the comparison, the highest r^2 value is 0.235 (n = 42). Furthermore, there is considerable variation between r^2 values given the three different sample sizes. As an example, the highest r^2 value between peak discharge and daily rainfall arises with a full sample (42 events), while the highest r^2 value for peak discharge and multi-day rainfall occurs when the 2005 flash flood event has been removed and the sample is reduced to 41 events (Table 5.13). The regression equation for this statistically significant relationship (Equation 5.1) was included within Section 5.4.2.

This analysis has identified several key limitations of the data, including the absence of detailed information about rainfall events during the full discharge record (back to 1978). Four data points within the discharge dataset represent overbank floods which appear to have taken place on the River Rye over the period for which discharge records are available (in 1999, 2000, 2005). Therefore, a pseudo *flood* series would be based on only a very small number of data points and would include both in-channel and overbank events. Based on these limitations, it would be difficult to create a reliable flood series (containing absolute values) using the existing rainfall data alone.

However, the bankfull discharge at the Broadway Foot gauging station is 122.9 $m^3 s^{-1}$ (contains Environment Agency information © Environment Agency and database right), for which Equation 5.1 produces a multi-day rainfall value of 62.5 mm. Therefore, the multi-day periods (of up to three days) where rainfall above 62.5 mm has fallen were identified within the rainfall series, suggesting an overbank flood event.

In total, for the duration of the rainfall record not covered by the discharge series (1st January 1916 to 23rd August 1977), the regression equation above produces 14 possible overbank floods (hence: POFs). It is notable that six of these are three day events (where the sum of three days of rainfall exceeded the 62.5 mm threshold). For the whole of the rainfall record (1916-2009), 31 POFs are constructed, with twelve three day events. Of the 42 initial discharge events used within the analysis, only two were long enough to incorporate three days of rainfall. Therefore, there is much greater confidence in the constructed one and two day POFs, which are the only events included in the following analysis. These events are shown below (Figure 5.19).

Figure 5.19: Timeline showing past floods within upper Ryedale, 1930-2009, as revealed using river discharge records, reconstructed possible overbank floods (using rainfall data) and floods mentioned within interviews (from upper Ryedale) and in questionnaires (from Helmsley). All floods revealed in the discharge record are overbank at the Broadway Foot gauging station. The diagram does not show a) vaguely recalled floods recorded within questionnaires (e.g. no year given) or b) very high river flows that were not floods recalled by interviewees. Floods from interviews marked by a circle (o) are vague recollections of a flood within a decade. Discharge data provided by the Environment Agency, except 19th June 2005 peak discharge (estimate by Wass et al., 2008); possible overbank floods based on rainfall data contained in the Met Office MIDAS database and data provided by the Environment Agency.

The accuracy of the POF method can be assessed by its identification of floods and high flow events which occurred during discharge monitoring at Broadway Foot (23rd August 1977 to the end of 2009). During this period, seven out of eleven POFs are associated with discharge events within the largest 50 flow events recorded. The POF method identifies large overbank floods in 1999, 2000 and 2005. A POF date in 2002 (1st August) may be associated with a peak discharge on the 2nd August of 87.8 $m^3 s^{-1}$, the seventh highest flow event recorded at Broadway Foot (Table 5.9). This peak discharge is below bankfull at the Broadway Foot gauging station, but it could have caused overbank flooding elsewhere. Indeed, some interviewees noted a high river flow (that did not breach the banks) at Helmsley in 2001-2 (Section 5.3.2), and more than one questionnaire respondent noted a flood in this year. A POF in 2004 (10th August) could be associated with a peak discharge of 68.8 $m^3 s^{-1}$, although this peak discharge is only the 15th highest flow event on record. Additionally, no POFs were identified at similar times to two other peak discharges within 2004 which were greater than 68.8 $m^3 s^{-1}$, and no POFs were constructed at the time of seven recorded high discharge events (between 75.2-104 $m^3 s^{-1}$). Therefore, a comparison of POFs and recorded high flows suggests that the accuracy of the method is only moderate.

However, during the period prior to river discharge monitoring, some POFs represent known flood events, and reflect overall rainfall patterns and recollections of floods from residents of upper Ryedale. The 1931 event (4th September) reflects known flooding throughout the North York Moors, including on the lowland River Derwent (Jones, 2000) and was discussed earlier within this section (Figure 5.11 shows the locations affected). The 1976 event (11th September) was associated with extremely high rainfall totals across the North York Moors (Figure 4.5) and documented erosion within the upper Ryedale catchment (Beven et al., 1978). The 1931 and 1940 POFs correspond to a decade of well above average heavy rainfall (Table 4.3). POFs in 1940, 1948, 1967 and 1976 were caused by extremely high daily rainfall values, within the 'top ten' daily rainfalls recorded in upper Ryedale (Table 4.2). Known overbank floods and POFs occurred within 19 years: 15 of these had above average annual rainfall, 16 had an above average annual frequency of heavy rainfall (as defined by the DR1 threshold (Section 3.7.1)), and 18 out of the 19 years recorded an above average proportion of annual rainfall falling on heavy rain days. The decadal frequency of known overbank floods and POFs (throughout the whole record from the 1930s onwards) has moderate correlations with the decadal mean normalised rainfall (coefficient = 0.29), the decadal frequency of heavy rain days (coefficient = 0.45, 2000s frequency adjusted) and the proportion of decadal rainfall falling on heavy rain days (coefficient = 0.38), although due to the very low number of data points (eight) none of these relationships are statistically significant. Therefore, there is a broad association of floods and POFs with periods of above average heavy rainfall.

Additionally, the seasonal distribution of known floods from the river discharge series (2005, two events in 2000, 1999) and POFs from the period prior to discharge monitoring shows the dominance of summer and autumn flooding within upper Ryedale, as half of the twelve events occur within autumn, five events occur in summer and one event occurs within spring. In the whole POF and known flood record, eleven out of 20 events occurred in summer, six within autumn, two within spring and just one event within winter. This reinforces the local perception of summer as an important season for flooding, and reflects the tendencies for a) heavy rainfall to fall more frequently in summer and autumn compared with other seasons (Section 4.1.3) and b) high flow events in summer and autumn to be more extreme (in terms of peak discharge, and rate of discharge increase) than those in other seasons (Figure 5.13). Furthermore, the temporal distribution of overbank floods and POFs reasonably reflects the memories of past floods recalled by local residents. The recent overbank floods in 2005, 2000 and 1999 are reflected in the clustering of floods recalled in the 1990s and 2000s by interviewees and questionnaire respondents. As described above, it is likely that other floods of the River Rye will have taken place in this period, as very high river flows (such as that in August 2002, signposted by a POF) could have caused overbank flooding at some locations, despite not being overbank at the point of river gauging. Additionally, questionnaire and interview recollections of floods from 1930-1960 are reflected in the reconstructed POFs during this period. In particular, flooding in the 1930s period was noted by a number of questionnaire respondents and some interview respondents (Figure 5.19). Aside from recalled floods in these decades (shown on Figure 5.19), five questionnaire respondents recalled a flood in the 1930s decade with no specific year, and seven respondents recalled a flood in the 1940s. The 1960s decade only records one POF, possibly representative of a 'flood poor' period (e.g. Lane, 2008) and the 'dry' nature of this decade (Section 4.1.1), with low heavy rainfall (Section 4.1.3). The contrast between 'flood rich' and 'flood poor' periods (e.g. Lane, 2008) is also evident in the clustering of recalled flood events in interviews and questionnaires, with a notable 'gap' in these records and a low frequency of recalled floods from the 1960s to 1980s (Figure 5.19). The high frequency of recalled floods in the 1990s and 2000s (Figure 5.19) by questionnaire respondents and interviewees is unsurprising, given the overbank flood events which occurred in 1999, 2000 and 2005 and other high discharge events, potentially indicated by some POFs during this period.

The fact that three POFs, and one additional large snowmelt-driven flood (in 1947, not picked up using the rainfall regression method, or river discharge monitoring) which occurred between 1931 and 1948 clearly emphasises the limitations of short-term discharge records in assessing flooding in an upland area. Secondly (and more importantly), large numbers of residents will not be aware of such events. This is because

a) the events are not well documented and b) not well known, except by older, long-standing residents who may have witnessed them. To emphasise the latter point, the mean age of questionnaire respondents who recalled floods in the 1930s and 1940s was 73.8 years (n = 8, 8/11 residents gave an age), approximately ten years older than the average age of the overall questionnaire sample (n = 156). Similarly, it is likely that a POF that occurred in 2002 was associated with a high river flow event that may have caused some overbank flooding, and other recorded high discharge events may have led to some flooding (despite not being gauged as an overbank flood). As knowledge of recent flood events has been found to be associated with changes to flood risk perception (Section 5.2.2.4) and experience of multiple floods is associated with flood responses (Section 5.3.2), local awareness of such events, in addition to large flash floods, may play an important role in influencing perceptions of flash flood risks and subsequent responses.

Identifying when past floods have occurred using multiple methods (interviews, questionnaires, discharge records and the ‘possible overbank flood’ method described above) is difficult and subject to some uncertainty. Personal memories of past flood events, as presented in the pseudo flood series above and also discussed elsewhere within this chapter, are inevitably inexact, as learning about floods from residents is dependent upon the nature of human memory (McEwen, 1987) and the flow threshold at which river flows are documented or remembered (Benito et al., 2004) is uncertain within upper Ryedale. Additionally, extrapolating the occurrence of overbank floods from one gauging station to a wider upland catchment is very difficult. However, this section has aimed to overcome the constraints of a short river flow record, typical of the poor river flow monitoring within upland areas (Macklin and Rumsby, 2007), and has presented an alternative method to identify past floods in an upland area.

5.5 Perceived factors influencing local flood risks

Questionnaire respondents were given the opportunity to write an open answer to the question “What factors contributed to the flood in Ryedale in 2005? Has anything occurred to increase the risk of flooding?” In total, 107 people provided responses to this question. Meanwhile, interviewees from 14 houses in Helmsley, Rievaulx and Hawnby were asked about their views on factors influencing local flood risk. The most commonly mentioned factors affecting flood risk in Ryedale in questionnaire responses are summarised in Table 5.15.

Factor	% of responses mentioning factor
Maintenance of rivers and streams	26.2%
Ditch/drain maintenance and issues	14.0%
Climate change	12.1%
Increased building on floodplains	10.3%
Agricultural drainage, land management	7.5%
Deforestation	1%

Table 5.15: Factors affecting the risk of flooding in upper Ryedale according to questionnaire responses (n = 107).

The maintenance of rivers and streams was the single most commonly mentioned factor, which appeared in just over a quarter of all responses (Table 5.15). The link between this factor and flood risk was succinctly summarised in one questionnaire comment:

> Streams and rivers never seem to be cleaned out anymore, so this results in them getting shallower/narrower, and as a result, unable to move as much water.

Other comments argued that a change in management practices had led to poorer maintenance of rivers and more rapid river level rise:

As late as the 1980s there were men who worked on the Rye clearing debris, overhanging foliage, weeds etc. although the river used to break into lower lying fields, it was nothing unusual. Since the environment agency took control of such waterways, all maintenance seems to have come to a halt. As a result, there is a build up of rubbish, debris from the 2005 floods, weeds etc., and as a result the river rises very, very quickly with just "normal rainfall".

A further comment pointed to an example of a local flood which had (in the view of the questionnaire respondent) occurred as a result of a lack of maintenance:

The clearing of debris and silt build up from under the arches of bridges is a major contribution to prevent flooding e.g. Gilling East.

Additionally, the maintenance of river channels was mentioned by several interviewees as a factor affecting local flood risk. An interviewee offered his views, firstly that a change in management practices had led to poorer maintenance, and secondly of the role of river debris in exacerbating the 2005 flash flood:

It is the progressive governments' approach that has caused this and it is just going to carry on until something is done. They used to pay farmers and land owners to keep the rivers clear – now they don't. They promote the wildlife, so if a tree falls down you leave it there because... so over the last eighty to one hundred years, well eighty years, every river bank in the country has got narrower and narrower and full of rubbish, so when there's a flash flood happens all it does is like it did down in Boscastle and here, they are what you could class in the same situation, us and them, the ones what happened last year were slightly different, but all it did was the water came off the hills, got caught up in little river beds, dragged all the rubbish down and it dammed up behind the back of footbridges and then it took that bridge out and you get to the next one, dammed up there, all this water just kept damming up and damming up and then here it got to the Church Bridge and once it finally knocked that down it came through as a "whoosh."

The resident also stated that the 'steward's scheme' was the reason why some people were paid to "...keep things natural". This refers to Environmental Stewardship, an English scheme which provides money to farmers and land managers to improve the environment (Natural England, 2011). Similarly, an interviewee in Helmsley offered the opinion that people could not remove dead trees from rivers any more due to environmental and scientific interests:

...Round here we have these dead trees and SSI areas... scientific... special scientific interest places. Well if anything is blown down they really can't touch it.

Some residents of Helmsley noted that debris was removed from the River Rye following the 2005 flood. One resident stated that following this work (carried out by the Environment Agency) water seemed to drain away faster. However another resident of Helmsley argued that the river maintenance had actually increased flood risks:

...We haven't had another (flood) since then, but what's upsetting me is the bridge this side they haven't dredged it. They've dredged the other side, but not this side. So the water can't go into the flood fields, so it comes to us. We'll get the lot.

Ditch and drain maintenance was mentioned as a factor influencing local flood risk by 14% of questionnaire respondents (Table 5.15), with additional links to changes in maintenance practices mentioned in some questionnaire comments:

Years ago men called gully cleaners went round villages cleaning out all the drains and ditches. These men have gone.

It was noticeable that the lack of maintenance of river channels, and the accumulation of debris on river beds was perceived as an important cause of local flood risks, as other upland rivers in North Yorkshire have suffered from river bed aggradation. For example, the upper River Wharfe catchment, near Buckden (Figure 5.1) is known to have suffered from recent coarse sediment aggradation, and associated morphological changes to the river channel are thought to have increased flood risk there (Raven et al., 2009). It was notable that the contention that rivers and streams were poorly maintained/not cleaned out regularly enough has also been made by local residents in other studies in the U.K., including in Scotland (Werritty et al., 2007) and in England (Environment, Food and Rural Affairs Committee, 2008; Ryedale Flood Research Group, 2008*a*; Cave et al., 2009). The Environment Agency, in its review of the 2007 floods in England and Wales, noted that a lack of maintenance of rivers and drains was one of the most commonly mentioned issues in flood surgeries, telephone calls and written correspondence following the floods (Environment Agency, 2007*b*).

It was interesting that the proportion of comments mentioning climate change as a factor influencing the risk of local flooding (12.1%) was less than half the overall number of comments which mentioned the maintenance of rivers and streams (Table 5.15). Most comments mentioned the broad concept 'climate change' or 'global warming' which is increasing the risk of flooding:

I consider the 2005 flood to have been (a) capricious freak of weather conditions which could have happened anywhere in the country. It will probably happen again sooner or later. Overall I feel climate change will increase such occurrences everywhere...

A minority of respondents were more specific in their thoughts on climate change, referring to changes in local rainfall patterns and increases in heavy rainfall. Further details of local views on rainfall are included in Chapter 4 (Section 4.4). One individual who mentioned climate change as a factor stated that he kept rainfall records, which suggested that rainfall totals were increasing, and provided a separate list of days with notable rainfall totals between 1997 and 2008:

Local rainfall figures show that recent years have been wetter than the previous decade!

While residents of upper Ryedale clearly showed an awareness of changes to the local climate, including the shift to more frequent and extreme heavy rainfall (particularly in summer) (Sections 4.1.2, 4.1.3), they were unlikely to state this as a driver of local flood risks, and were more likely to state that river maintenance was the foremost issue affecting local flood risks. Similar findings were discovered by Whitmarsh (2008) who found that“...flood victims view climate change and flooding as largely *separate* issues” (Whitmarsh, 2008: 368, emphasis as in original). Additionally, “...personal observation was evidently the most trusted source of information about the causes of flooding” (Whitmarsh, 2008: 368). Similarly, Lave and Lave (1991) noted that flood events were often perceived as 'man-made' by those affected, while climate change is rarely framed into local surroundings (Lorenzoni et al., 2007) and the public require the means to place short-term, local weather into the wider, global climatic context (Rebetez, 1996). Additionally, such attitudes may reflect respondents disassociating themselves from the impacts of climate change (Whitmarsh, 2009) or represent a wider public scepticism about climate change and its impacts (British Broadcasting Corporation News, 2010). Despite survey evidence suggesting that the public strongly agrees with the need to combat climate change (Thornton, 2009), other research suggests uncertainty and distrust among the public relating to information received about climate change, as well as a belief that its impacts will occur in the distant future (Lorenzoni et al., 2007).

Other factors mentioned by questionnaire respondents as affecting the risk of flooding in Ryedale included building houses and development on floodplains (c. 10%) and agricultural management (7.5%) (Table 5.15). Most of the comments referring to house building were a variation of ‘people should not build on floodplains’, however the production of larger volumes of surface water as a result of floodplain developments was also mentioned. This topic was mentioned by some interviewees also, including a resident of Helmsley:

Do you think people have done anything to increase the risk of flooding in Ryedale?

They've built more houses in Helmsley, and I think they've tended to put drainage systems and guttering and that to take surface water into the main drains, and I think they've tended to overload them a lot.

Another resident of Helmsley argued that local knowledge was often not taken into account in the planning and building process:

…I think planners and local authorities choose to disregard known folklore. If you talk to (name), the butcher, who has grown up here, and his family were here, he knows which fields flood, but the authorities don't always listen to the community. It's the older people who could really tell you, and that information needs to be recorded before it's lost.

Some interviewees from Helmsley pointed out that surface water and drain flooding had previously been common in the Ryegate area after heavy rainfall. Since then, improvements had been made to the drainage and sewerage systems in this area of Helmsley, and the consensus among interviewees was that the new drainage system has improved this situation.

With regards to agricultural management, some questionnaire comments pointed out the links between drainage on the moors and increased transfer of waters to rivers:

I believe an important reason for flooding in Ryedale is the improved drainage on the moors where water is not held in the peat and is released straight into the streams and rivers.

Another comment suggested that the use of heavy tractors was compacting the soil:

It is my belief that the use of the present day, monstrous heavy tractors compact the soil below the top six inches of till, thus causing surface water to run off quickly instead of seeping into the under lying layers.

Agricultural management was only tentatively mentioned in two interviews, and was clearly not perceived to be an important factor affecting local flood risk. Agricultural land management in general constitutes a known influence on runoff and therefore flooding (O'Connell et al., 2005, 2007; Wheater and Evans, 2009). Changes to upland land management may have influenced flooding in some parts of northern England (Lane, 2003; Orr and Carling, 2006).

A number of local residents stated that they had heard that the 2005 flood was caused, or exacerbated by, the breaching of a dam in the upper catchment. Furthermore, some residents in Helmsley thought that the dam breach was the main cause of the 2005 flood, as opposed to the flood being solely caused by the heavy rainfall:

> At the time, there was talk of a reservoir, wasn't there, up above Rievaulx right up… and they said that had burst, and that's what caused it. But that's what I heard, that was the main cause of it. It added to the floods that we got, so you know…

It is possible that this view may have affected hazard perception: people viewing the cause of the flood as a dam burst or breach (a very rare event) may have been less likely to view the flood as likely to recur.

5.6 Discussion and chapter summary

Through a combination of questionnaire data and information collected during in-depth interviews, it was possible to assess responses to the 2005 flash flood by the residents of Helmsley and rural communities in upper Ryedale. Responses to flash flooding, and the factors affecting them, can be placed in the context of recent national policies to deal with flooding, which have shown a move towards improving awareness of flooding and encouraging individual actions to increase property-level resilience to flooding (Section 1.3).

Although the flash flood directly affected a relatively small area of the town, a much larger number of people witnessed the flood, were involved with dealing with the aftermath of the flood, or knew someone who was directly affected. It is unsurprising therefore that majorities of those surveyed stated that they had discussed flooding with other residents, and had become more aware of weather forecasts and river and stream levels since the 2005 flood. However the awareness of flood warning and flood information services provided by the Environment Agency, including the Floodline warning service, flood maps and flood warning symbols was found to be poor throughout Helmsley. The low awareness of such services among the surveyed population (many of whom lived in an area with an assessed, relatively high risk of flooding), particularly in the years after a major flash flood may appear surprising. Research has shown that accessing the flood map does motivate some of its viewers to take further action - a survey of flood map viewers found that 4-13.5% of respondents who had visited the Environment Agency's online flood map made responses to flooding in response to the website, although such responses were most likely to be low-cost and require little effort (signing up for flood warnings) rather than more expensive options such as taking up flood insurance or physical modifications to property (Priest et al., 2008). Those who had experienced flooding personally, and perceived a higher flood risk, were more likely to take action after viewing the site (Priest et al., 2008).

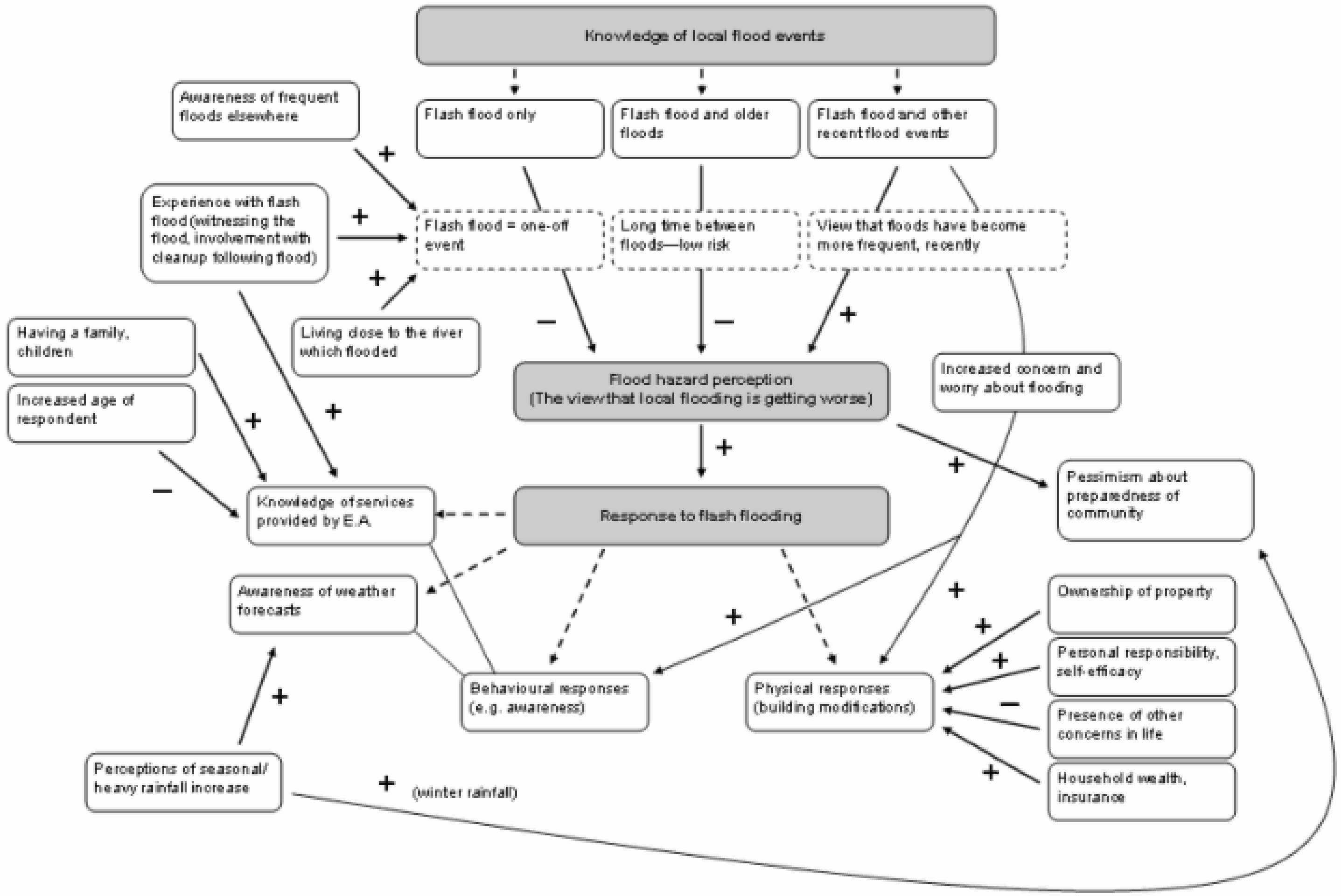


Figure 5.20: Summary of the factors influencing responses to flash flooding and the perception of the flood hazard, based upon interview and questionnaire responses of residents. +/- signs indicate the nature of influence of factors upon responses/perceptions.

The factors found to influence responses to flash flooding are shown in Figure 5.20. This is based upon the household-level responses to flooding assessed using interviews, and also includes some of the variables found to be associated with flash flood responses and perceptions during the questionnaire analysis of the wider population of Helmsley. Among those who were directly affected by flooding in 2005, physical responses to the flash flood tended to be minor, including the installation of small wooden barricades for doors, and the rebuilding of walls to a greater height. Some properties in low-lying areas had carried out larger physical modifications, and one respondent was involved in building the river bank up near his property prior to the 2005 flood. The most extensive modification made to the flash flood of 2005 was the abandonment of an old property and the building of a new one, in Hawnby. While physical modifications to flash flooding tended to be limited in most cases, those who had been affected by the flash flood in 2005 had made several behavioural changes as a result of the flooding. These included a greater awareness of river levels (including worrying when the river gets to a certain level), being more aware of weather forecasts and heavy rainfall events (including taking actions during heavy rainfall events, in case the river rises), and keeping valuable or important items at a higher level. Most interviewees showed some confidence that their responses to flooding would be effective at reducing damage in the event of a future flood.

Although the awareness of some of the Environment Agency's services appeared to be higher among directly affected residents than amongst the general population as a whole, some individuals who had used the services were unsatisfied with them. Complaints about the services included poor advice given during the 2005 flood and a view that the warning services were remote from local concerns. As national policies have stressed the importance of increasing awareness of flood risks and household resilience to flooding (e.g. DEFRA, 2005; Pitt, 2008), it appears that the rarity of the flash flood hazard in this upland catchment did not provide a 'trigger' to do this. Similarly, De Marchi and colleagues found that experience of a flash flood event "...was not a catalyst for the adoption of household precautionary measures" (De Marchi et al., 2007: 76). There was some similarity between the factors found to influence responses to flash flooding in this study and the models of hazard response in the literature. In particular, the relationships between past knowledge and understanding of local flood events and flooding, and their implications for perception and concern over future flood risks, were similar to the concept of threat appraisal outlined by Grothmann and Reusswig (2006) in their proposed model of factors influencing protection motivation. This model is an adaptation of Protection Motivation Theory (P.M.T.) which assesses social and cognitive factors as explanations for adaptive and protective behaviour (Milne et al., 2000). Grothmann and Reusswig also identified coping appraisal and self-efficacy as key components of their model, as well as what were described as “...non-protective responses”: fatalism, denial and wishful thinking (Grothmann and Reusswig, 2006: 105). Attitudes related to such responses were found in this study, and as factors such as wealth, ownership of property and perceived responsibility for responses were identified as factors influencing physical responses to flash flooding (Figure 5.20), these appear closely related to coping appraisal, as well as constituting “...actual barriers” to mitigation measures (Grothmann and Reusswig, 2006: 105). The model was described by the authors as a “...socio-psychological model” (Grothmann and Reusswig, 2006: 101); a similar model proposed by Paton (2003) also includes a number of the attitudinal factors influencing responses to flooding uncovered in this thesis. The strength of these factors is reinforced by Lin et al. (2008) whose study into flooding in Taiwan discovered that “...psychological variables are stronger predictors for mitigation intentions than that of socio-economic variables” (Lin et al., 2008: 305).

Additionally, attitudinal variables constitute an influence upon ‘cognitive factors’, which affect hazard perception (Tobin and Montz, 1997; Figure 2.3).

Among those directly affected by the flash flood event in 2005, behavioural adaptations were more prevalent than physical modifications to property. The most common behavioural changes included greater awareness of river levels (including the concept of a 'panic' or 'worry' river level, with action being taken after this was reached), taking a greater notice of weather forecasts and actions being taken after heavy rainfall, and keeping valuable or important items at higher levels. Similarly, questionnaire analysis (of the wider population of Helmsley) indicated that respondents’ perceptions of changes to local rainfall were significantly associated with changes to the awareness of weather forecasts since the 2005 flash flood. In smaller catchment areas, particularly in remote locations, decisions to respond to flooding are often made at the individual scale based upon observations of the environment, rather than after warnings from organisations (Creutin et al., 2009); therefore, evidence of behavioural changes found in this study is a positive development from the viewpoint of flood risk management. Greater awareness and worry about river levels and heavy rainfalls has been found in many studies of flood knowledge and responses in the U.K. (Burningham et al., 2008; Tapsell and Tunstall, 2008; Whittle et al., 2010). In this study, houses where the largest behavioural (and physical) responses had been made tended to be those where interviewees expressed concern, or uncertainty, over future flood risk, and/or had experienced more recent flooding (including a minor flood in 2000 as well as the flash flood in 2005) (Figure 5.20). Some stated that they thought that the flash flood was a one-off event, but later in the interview expressed uncertainty as to this view; others stated that they thought about flooding during heavy rainfall or when the river was rising (exemplified by the ‘panic levels’ described above) and a property which had experienced flooding three times in its history was by far the most extensively modified. Additionally, when asked what it would take for them to do more to protect their houses from flooding, some stated that the occurrence of another flood would do so. Furthermore, questionnaire respondents who agreed with the view that flooding of the River Rye was getting worse were more likely to recall a higher number of recent floods (within the 1990s and 2000s) on average than those who disagreed with the statement. It is possible that some of these ‘floods’ may be associated with very high discharges (though not overbank floods at the gauging station): for instance a high flow in the early 2000s was recalled at Helmsley and additionally was identified by an assessment of possible overbank floods (Section 5.4.4). Flood experience was therefore associated with hazard perception. Similarly, questionnaire respondents who perceived that flooding of the River Rye was getting worse, or perceived a higher risk of flooding in the future, were more likely to be more aware of river levels since the 2005 flood. Additionally, as questionnaires suggest that those with families (implied by more than one adult living at home, or children living at home) are more likely to know what some Environment Agency services are than those living alone, or without children, it is possible that greater concern for family residents is a motivating factor in an individual seeking such services: a questionnaire study into flood risk perceptions in Romania indicates that correlations exist between a resident's perceived personal damage (including to his family and household) and fear of future flooding (Armaş and Avram, 2009). Similarly, Pynn and Ljung (1999) found that the likelihood of a house having flood insurance was slightly increased if children lived at home, and risk perception generally increases if a person is a parent or if children are exposed to risk (Whyte, 1986).

The literature suggests that the fear of (or concern over) future flooding, often related to past experience with flooding, is an important factor in encouraging increased risk perception and responses (Waterstone, 1978; Hansson et al., 1982; Blanchard-Boehm et al., 2001; Zaleskiewicz et al., 2002; Paton, 2003; Takao et al., 2004; Ho et al., 2008; Raaijmakers et al., 2008; Siegrist and Gutscher, 2008). More frequent experience of involuntary risks, that have affected lives in a negative way, is associated with increased concern about them (Barnett and Breakwell, 2001). Some studies have suggested that fear of flooding is more important than knowledge of flooding, or a rational assessment of flood risks, in leading to responses (Zaleskiewicz et al., 2002; Takao et al., 2004; Miceli et al., 2008); although other studies have argued that those who have experienced flooding are "...less willing to adopt mitigation measures" than the public as a whole (Lin et al., 2008: 312). Fear and stress is particularly related to the recency and repetition of flooding (e.g. Hansson et al., 1982) and such emotions are generally unfelt by those who have not experienced flooding before (Siegrist and Gutscher, 2008). Research following major flood events in the U.K. has documented the serious, complex impacts of flooding on mental and physical health, particularly among vulnerable groups (Tapsell et al., 2002; Tapsell and Tunstall, 2008; Whittle et al., 2010).

With regards to experience of flooding, the important link between hazard experience and self-protective behaviour among individuals has been suggested in the literature (Weinstein, 1989) and the contention that societies which suffer a high frequency of extreme events are more likely to adapt to mitigate against the events is seen as broadly true (Tobin and Montz, 1997). Experience of past flash flood events is important, as "Past experience with flooding and perceived risk play a key role in shaping the way that a person will approach flash floods" (Knocke and Kolivras, 2007: 167); similarly, the experience that an individual has with a hazard improves their understanding of it (Wagner, 2007). Several studies have suggested a link between greater experience of flood events (including experiencing multiple flood events, and/or a large flood occurring recently), and personal- and household-level responses to flooding and flood preparedness

(Harding and Parker, 1974; Waterstone, 1978; Irish and Falconer, 1979; Hansson et al., 1982; Laska, 1990; Correia et al., 1998; Burn, 1999; Wind et al., 1999; Browne and Hoyt, 2000; Haque, 2000; Kreibich et al., 2005, 2011; Knocke and Kolivras, 2007; Priest et al., 2008; Kreibich and Thieken, 2009). Additionally, those who have experienced past flooding have been found to save a greater number of items, and prevent more damage, than those who have not experienced flooding upon receipt of a flood warning (Parker et al., 2007). In upper Ryedale, experience of flash flooding increased the awareness of the flash flood hazard, and provoked some changes to residents' behaviour and actions. The fact that some residents of upper Ryedale became more observant of heavy rainfall, river levels and weather forecasts suggests that aspects of 'unofficial' warning systems (Parker and Handmer, 1998) had become more apparent in the area since the 2005 flash flood. Communications between neighbours and other informal sources of information, as well as a resident's past experience of living in an area, have been found to predominate over 'official' flood warnings in England and Wales (Steinführer et al., 2009).

However, it appears that the nature and characteristics of flood experience among residents of upper Ryedale was the most important factor in influencing responses to flooding. Generally, experiences and memories of flooding prior to 2005 tended to be of minor local flooding (including surface water flooding and sewer/drain flooding in Helmsley), of regular high river flows (leading to some low-lying fields being flooded in most years) and river floods in the early to mid-20th century (some of which occurred due to snowmelt) that saw river levels rise slowly. The physical environment, including the nature of hazard events and their occurrence, and their influence upon hazard experience, constitutes a variable influencing the 'situational factors' that in turn affect hazard perception (Tobin and Montz, 1997, Figure 2.3). Therefore, the flood experience of residents prior to 2005 in no way prepared residents for a larger, 'flash' flood event or led them to believe that one could occur. Burn (1999) argued that experience is only relevant if flood events are similar in character to those which have occurred before, and Weinstein (1989) stated that responses/precautions to hazards are made which are proportional to the nature and degree of hazard experienced. Experience with certain types of flooding can therefore prevent effective responses to other floods: in the statement of Kates (1962), "Men on flood plains appear to be very much prisoners of their experience" (Kates, 1962: 140). Similarly, following a flood event, those affected often form a view of floods and their causes, which influences their perception of flood risks (Green et al., 1991): however if bigger floods occur, the limitations of this experience is clearly revealed (Steinführer et al., 2009). Therefore, the experience of minor floods (those causing little threat or damage, as in upper Ryedale) may lead to a presumption that floods in the future will also cause relatively little damage, despite an increase in flood risk perception (Burningham et al., 2008; Botzen et al., 2009) and experience and knowledge about past floods can still leave people ignorant of the effects of rainfall and flooding, if they had occurred in different ways (Werritty et al., 2007). In this study, some residents that had witnessed or experienced a smaller flood had found the mitigation measures taken (e.g. barricades, sandbags) to be useless during the flash flood. The lack of recent local experience with severe flash floods therefore hindered the response to the 2005 flood event, as the extreme nature of the event was unprecedented. Therefore, there is support for the view expressed by Weinstein (1989), who stated that experience "...is commonly treated as an undifferentiated, all-or-none variable" (Weinstein, 1989: 37). In fact, the nature of flood experience, including its timing, character and recency, is the most important factor influencing flood hazard perception. Questionnaire analysis in this project found, somewhat counter-intuitively, that those who agreed that the flash flood in 2005 was a one-off event were more likely to live closer to the River Rye than those who did not think that the flash flood was a one-off event. Furthermore, those questionnaire respondents with some experience of the flash flood (being involved with the cleanup after the flood, or knowing someone who was directly affected by flooding) were also more likely to agree that the flash flood event was a one-off. Those who were involved in the cleanup after the flood were also more likely to disagree with the view that local flooding was getting worse: involvement in cleaning up after flooding has been found to be associated with higher risk perception (Siegrist and Gutscher, 2006). Research into flash floods has suggested that observing flash flood impacts on local households can increase perceptions of these events (Knocke and Kolivras, 2007); however, in this study, the character of past knowledge of local flooding appeared to override the damage and disruption caused by a flash flood event. In upper Ryedale, there were potential links between the perception of the flash flood event and the pattern of high flows in the river catchment revealed by discharge records (running from 1978-2009). In particular, high flow events other than the flash flood were not becoming larger in magnitude, or becoming faster rising in nature. Furthermore, the lag time between rainfall and river discharge responses is usually much longer than that experienced in the flash flood event. Therefore, such patterns lend support to the view that the 2005 flash flood event was unusual.

A further factor influencing hazard perception was the contrast made by several residents between nearby areas which experienced relatively regular flooding, and the 'one-off' nature of the local flash flood. As a result, flood risks were perceived to be higher elsewhere, despite the greater danger posed by the flash flood in 2005. Waterstone (1978) and Kunreuther et al. (1985) noted the tendency for moderate, frequent flood events to cause a higher response (the purchase of flood insurance) compared with a large, infrequent flood event; a development of the theories of Burton et al. (1968). Indeed, there can be large differences between flood preparedness among different parts of the same region, based upon variable flood experience, the strength of memories of flooding within a community, and the perception of the rarity of other recent floods (Burn, 1999). Similarly, a study into responses to flooding in Germany found that when an extreme flood was followed by a large, but less damaging flood, the second flood led to a greater increase in the perception of future flood risk (Kreibich et al., 2011). The importance of the frequency of hazard events in influencing flood adjustments has been found in other studies (Harding and Parker, 1974) and classic hazard theory suggests that the frequency of hazards influences adjustments to them (Burton et al., 1968; Kates, 1971). In this thesis, questionnaire analysis suggested that there was an association between certain types of experience of flash flooding in 2005 and a lower perception of flood risks; however, greater overall flood knowledge (related to the frequency of recent floods recalled) was associated with perceptions that local flooding was getting worse. Similarly, some residents stated that experiencing or witnessing another flood would lead them to consider protective measures for their dwelling. This raises an important difficulty in individual and household-level responses to flash flood events in particular: by definition, flash floods are rare events (Gruntfest and Handmer, 2001, Creutin and Borga, 2003; Borga et al., 2008) which in turn reduces the likelihood of preparation for them (Montz and Gruntfest, 2002). Residents in rural areas are unlikely to have experienced flash flooding, and when very large floods occur following periods of relatively minor flooding, societies are unlikely to be prepared for them (Kundzewicz et al., 1999), and such major floods may be viewed as one-off events. This perception arises in the context of a likely increase in U.K. flash flood risks due to climate change (Weaver, 2007) and increasing rainfall intensities in the U.K. (e.g. Wilby et al., 2007; Maraun et al., 2008) as well as the transition to a flood rich period (e.g. Lane, 2008), presenting a complex problem for those institutions trying to mitigate against flash flood risks.

Importantly, many of those directly affected by the flash flood in 2005 viewed the flood as a one-off event and were largely unconcerned about the possibility of future flooding in the area. This was despite the flood causing considerable distress, damage and inconvenience to those who it affected: some residents spoke of being rescued or having close family members rescued, suffering major property damage, and spending a long time (up to six months) away from their houses. Despite this flood experience, those directly affected by the flash flood generally did not feel that it would happen again. This appears unusual, as a large number of studies have shown a link between experience of flooding and increased perception of the flood hazard (Parker and Harding, 1979; Krasovskaia et al., 2001; Keller et al., 2006; Siegrist and Gutscher, 2006; Knocke and Kolivras, 2007; Wagner, 2007; Ho et al., 2008; Botzen et al., 2009), probably reflecting psychological processes including the availability heuristic (Tversky and Kahneman, 1973, 1974) and the affect heuristic (Slovic et al. 1981, 2004; Slovic, 1987; Finucane et al., 2000; Loewenstein et al., 2001; Slovic and Peters, 2006). However, hazard experience is often found to be only slightly related to changes in behaviour, and a number of complex factors also influence responses (e.g. Sims and Baumann, 1983). Therefore, flash flood experience in 2005 may not have raised future hazard perception among many residents for a number of reasons. For instance, there are known difficulties which people have in estimating the likelihood of low probability risks (Camerer and Kunreuther, 1989). While residents living in areas which have suffered frequent flood events tend to be aware and knowledgeable of flood risks, and are therefore willing to take measures to protect against flooding (Baan and Klijn, 2004; Brilly and Polic, 2005), in areas of infrequent flooding, low risk perception, a casual attitude and more limited responses occur (Vari, 2002; Messner and Meyer, 2005), as effective flood protection and adaptation to risks at the local level is based upon past experience with similar flood events (Haque, 2000). Studies have suggested that those who live in areas at risk of flooding, but where flooding is infrequent, are unlikely to have experienced flooding, have low risk perception and are unlikely to take mitigation measures, (e.g. insurance) (Montz, 1982; Epple and Lave, 1988). A very large event may be viewed as rare, and not demanding of increased response (Mitchell et al., 1989); similarly, the extreme nature of flash floods may mean that residents do not view them as personally manageable, a viewpoint that may actually decrease the willingness of individuals to take personal responsibility for mitigation (Laska, 1986): hazard victims feeling powerless may reduce mitigation (Lin et al., 2008). Additionally, those that have experienced natural hazards can underestimate negative outcomes from such hazards, or believe that another disaster will not affect them, or be less serious if it does (Halpern-Felsher et al., 2001; Botzen et al., 2009). These attitudes are examples of the psychological belief known as unrealistic optimism: the belief that negative events are unlikely to be personally experienced (Weinstein, 1980). For instance, people may be aware of a general flood risk in an area, but believe that they personally are safe (Krasovskaia et al., 2001). An additional tendency for flood events to be forgotten quickly has also been noted (Harding and Parker, 1974). Although the events of the 2005 flash flood were extremely clear in the minds of those residents who had experienced them, as time has passed and memories of flood experiences become less clear (Tobin and Montz, 1997), the motivation to respond to the flood event also declines with time (Baumann and Sims, 1978). Finally, the same event may be experienced in a variety of ways by different residents of the same community, causing associated variations in risk perception and mitigation following the event (McGee et al., 2009); as an example, individuals with flood experience, but who have not been affected seriously (property damage) may perceive a higher flood risk but believe that damage in future will be low (Botzen et al., 2009). Furthermore, even where individuals have a perception that flooding will occur in future, the view that flooding will damage property in future has a more important link to response to flooding (Blanchard-Boehm et al., 2001, flood insurance).

Furthermore, a number of more ‘practical’ factors, including the cost of flood responses and individuals not owning their homes, were found to inhibit physical adaptations to houses in particular. Those who own their homes, rather than renting, have been found to be more likely to make responses to flooding (Waterstone, 1978; Takao et al., 2004; Zhai and Ikeda, 2006). In this study, individuals who rented a house frequently stated that the responsibility for protecting the dwelling against flooding wasn’t theirs. This is linked to the findings of Mulilis et al. (2000) who suggested that homeowners felt more responsible for preparing for natural hazards (tornados) than those who rented a property; in addition, homeowners tended to have higher resources for taking preparedness measures. Similar findings were made following flood events in Europe by Kreibich et al. (2005). There is a further link to income, which has been identified as a factor in the uptake of flood insurance (Browne and Hoyt, 2000, Steinführer and Kuhlicke, 2007) as well as in societal and household hazard adjustment generally (Burton et al., 1993; Kunreuther, 2006; Lindell and Hwang, 2008). Similarly, those in higher social grades were found by Parker et al. (2007) to save a higher monetary value of property after receiving a flood warning, based upon a study in England and Wales. Furthermore, Siegrist and Gutscher (2008) found that the high cost (and perceived lack of effectiveness) of flood mitigation measures was a reason why individuals with flood experience, and concern about future flooding, had not responded to the flood event; similarly, the cost and resources available to undertake flood protection is a factor which can reduce protection motivation (Grothmann and Reusswig, 2006). Some directly affected residents interviewed in this study had other reasons for not making protective adjustments, including fears about crime (putting flood doors on their house would indicate that the residents had left) and not wanting to worry about the risks of flooding. This supports the findings of Thurston et al. (2008) who found that a "...complex mix of barriers" (Thurston et al., 2008: 14), mirroring several factors discovered in this survey, stopped householders at risk of flooding in the U.K. from taking property-level protective actions, for instance “...they feel they are expensive or not their responsibility” (Thurston et al., 2008: 4); reasons and opinions given by residents for not protecting homes against flooding were also noted in Norwich Union (2008). Such views may be symptomatic of residents not appreciating the long-term benefits of responses (Kunreuther, 2006); also, if risk perceptions are raised, a number of other factors may intervene to prevent responses and adaptations to hazards (Paton and Johnston, 2001; Paton, 2003). The research findings from upper Ryedale, with behavioural responses to flash flooding relatively common but physical increases to property resilience much less so suggests agreement with the idea postulated by Kirschenbaum that “...risk-event perceptions induce individuals to perform preparedness behaviors that are in general relatively easy to achieve” (Kirschenbaum, 2005: 118). In other words, increases in risk perception may not provoke the uptake of more costly or difficult mitigation behaviour, such as physical modifications to property.

Descriptions of the 2005 flash flood as a ‘one-off’, a ‘freak’ or an ‘act of God’ by local residents represented, to some extent, a denial of future flood risks. This constitutes a common response to hazards (Burton et al., 1968; Tobin and Montz, 1997) with natural hazards also often seen as inevitable (Renn, 2004). The denial of hazard is a common response among lay people to deal with the uncertainty of hazards (Burton et al., 1968). Studies in the U.K. have found that many floodplain residents deny the existence of flood risk in their area, despite knowing about it (Burningham et al., 2008; Norwich Union, 2008; Pitt, 2008; Parker et al., 2009); residents of floodplains have been found to have a low perception of flood risks and an apathetic attitude (McPherson and Saarinen, 1977).

Denial of flood risks sometimes occurs as those who have been affected by flooding "...(do not want to) grapple with the possible reoccurrence of such a cataclysm" (Lave and Lave, 1991: 262). Those living in an area at risk of hazards often take a short-term view, and ignore or underestimate the probability of hazard occurrence (Kunreuther, 2006). Sometimes, denying a flood risk will lead to lower costs than taking actions to protect against the risk (Green et al., 1991) and such attitudes such as threat denial play an important role in reducing motivation for hazard responses (Grothmann and Reusswig, 2006). Some interviewees, whose only experience of flooding in the area was in 2005, contrasted the 2005 flash flood in Ryedale with the more regular flooding occurring in other parts of the region (e.g. at Pickering): this may represent a mechanism of risk denial whereby an individual claims to be less subjected to risk than others (Sjöberg, 2000). Similarly, the view stated by some residents that the flash flood would not occur again since a large period of time had passed since the last major flood in the region also constituted an attempt to remove uncertainty about the hazard (Burton et al., 1968). A number of views about flood risk discovered amongst residents of upper Ryedale in this study have been often found among other residents in the U.K., including denial and/or doubt over local flood risks, the belief that floods are an ‘Act of God’ or similar, and the belief that authorities do not understand issues or are otherwise incompetent (Borrows, 2006). The latter paper argued that “...there are deep-seated psychological reasons why difficulty is experienced in raising awareness of risk and getting people to take action to mitigate the risk” (Borrows, 2006: S135).

Other interviewees remarked upon the long time period between the 2005 flood and the last large, well-documented flood in the region (which occurred in the 18th century), or the tendency for the area to have experienced more manageable and lower-risk flooding in the past. Several interviewees were aware of increasing flooding nationally, and local increases in heavy rainfall in summer, however these trends were not viewed as being related to the local area and did not seem to influence local risk perceptions. Links between greater flood experience and risk perception were further reinforced by questionnaire data, which suggested that those who believed that local flooding was getting worse were more likely to have knowledge or experience of more recent floods of the River Rye than those who did not think local flooding was getting worse. Therefore, the experience of a higher number of local floods, rather than just the experience of the single 2005 flash flood, appears to be associated with increased flood risk perceptions. Evidence from interviews shows that experiencing multiple floods was linked to greater concern about flooding, and also physical, household-level responses to flooding, supporting this analysis. As well as knowledge of very large overbank flood events, residents may also recall other very high river flows that could cause overbank flooding in some areas, some of which have been identified as possible overbank floods within this chapter. Awareness of such events (such as a high discharge event in 2002, recalled at Helmsley), may play an important role in influencing hazard perception. Additionally, the possible overbank flood analysis has also highlighted potential floods throughout the 20th century. Furthermore, the questionnaire analysis found that the perceived preparedness of the local community (residents and local authorities) for future flooding was associated with perceptions of local river flooding, and perceptions of changes to local (winter) rainfall.

In both interviews and questionnaires, there was a strong view from residents of Helmsley and upper Ryedale that the poor maintenance of rivers and streams (caused largely by a change in management practices) was the most important factor affecting local flood risks. Many residents were highly knowledgeable about the local area, and several (in both interviews and questionnaires) offered insights into factors affecting local flood risk.

To a large extent, the responses to the flash flood, and attitudes to the possibility of future flooding, by residents (both those directly affected by flooding and the wider population) were representative of the nature of the flash flood hazard itself. Rare floods, for which preparation is difficult, are the flood events which need the most preparation (Burn, 1999). Flash flood specific studies have shown that flash flood knowledge is basic among those at risk (Knocke and Kolivras, 2007), and awareness of all types of flood risks have been assessed as generally low in the U.K. (e.g. Burningham et al., 2008). Experience with a hazard, and how visible hazard processes are, are the most important factors in the understanding of that hazard (Wagner, 2007). This case study has shown that the occurrence and experience of a flash flood has led to behavioural changes and generally limited physical modifications to properties. The relative (regional) rarity of the event and the lack of other flash flood experience (particularly in contrast to knowledge of more frequent flood events in the region, where flood risks are perceived as higher) clearly inhibited awareness and responses to flash flooding among many in this upland area.

Chapter 6

Institutional responses to flash flooding, and their implementation

This chapter analyses the responses of institutional stakeholders to flash flooding in upper Ryedale in 2005, and their implementation at the local level. Interviews were carried out with two spokesmen from the Environment Agency who were involved in the Agency's response to the 2005 flash flood (referred in the text as EA Interviewee 1 and 2) and a representative from Ryedale District Council (RDC Interviewee). Further information about these interviews is included within Section 3.8.1. This chapter presents the findings from these interviews. The chapter is structured into five main parts. Section 6.1 details institutional difficulties in dealing with the flash flood hazard, from the viewpoint of the Environment Agency and District Council. Section 6.2 details responses to flash flooding made by the Environment Agency. Section 6.3 outlines the potential for flash flood warning systems, while Section 6.4 compares institutional and local viewpoints. Section 6.5 comprises the chapter summary and discussion. This chapter discusses both the local (upper Ryedale) experiences of flash flooding, and wider policy changes made in response to flash flooding. A description of the institutional responsibilities for managing flood risks is included within the literature review (Section 2.4). Throughout the chapter, boxed quotes in bold text show re-worded clarifications to phrases made by an interviewee after the interview. Discharge data included in the chapter (Section 6.3) was provided by the Environment Agency, and further details of the analysis completed and records used are included in Section 3.7.2. Places named in the text are shown on Figure 6.1.

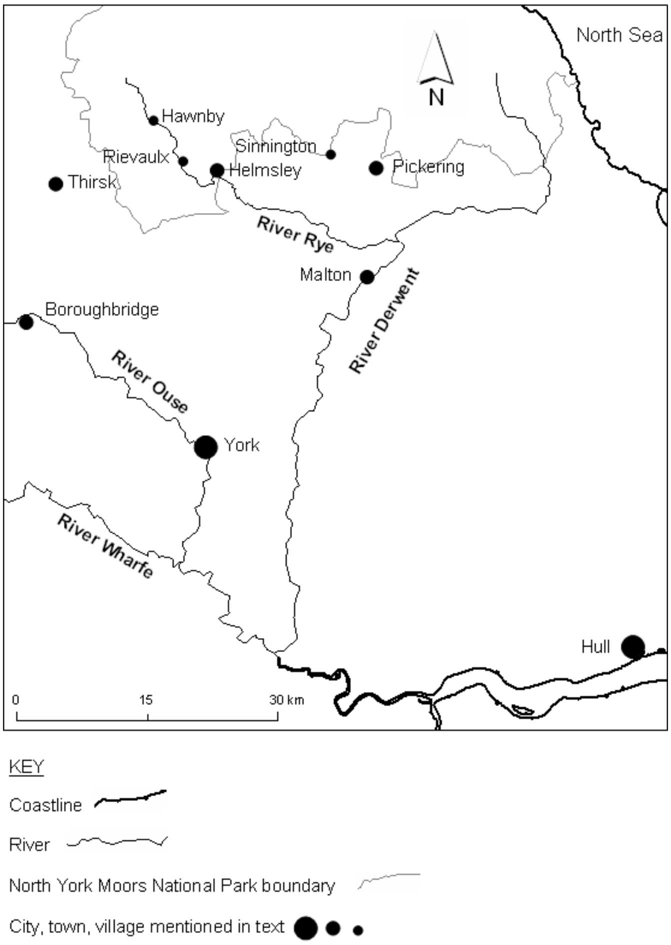


Figure 6.1: Places named in the text of Chapter 6. Diagram contains Ordnance Survey Strategi® data: © Crown Copyright/database right 2011. An Ordnance Survey/EDINA supplied service.

6.1 Institutional difficulties in dealing with flash flooding

Overall, the difficulties in dealing with the flash flood hazard from the viewpoint of the two Environment Agency spokesmen are best described as technical and financial. A difficulty exists in forecasting the unpredictable and localised rainfall events which cause flash flooding in sufficient time to warn residents at risk of flooding. Secondly, the lower population of rural areas means that it is difficult to justify work on large flood defence schemes in those locations:

The technical difficulty is providing lead-times for the forecasting, so two separate things forecasting and detection both things that are difficult for these type of events. And then justifying capital flood defence schemes in rural areas is something that's really difficult to do at the moment as well, just because the impacts are quite low. So I think it needs a change in policy like we're starting to see where it looks at the risk to life as well as the financial and economic benefits.

EA Interviewee 2

Similarly, the Ryedale District Council representative showed a good knowledge about the flooding history of the Ryedale district as a whole. He stated that the main flooding concerns in the catchment (at the time of interview) were at Pickering and Sinnington (Figure 6.1). Also of concern was the lower Ryedale district, around the River Derwent and in particular the Malton area (Figure 6.1) that had experienced major flooding in 1999 and 2000. So despite the extreme nature of the 2005 flash flood, Helmsley, Rievaulx and Hawnby (Figure 6.1) or upper Ryedale more broadly were not mentioned as a major concern. Also, the upper Ryedale flash flood event was described by the council representative as something which he had never come across before, despite his experience with flood events across the catchment. The rarity of the flash flood event at a local level was clearly apparent:

This was the first time I've ever encountered an event like the Hawnby event.

Okay.

It was totally different to what we are normally used to.

RDC Interviewee

6.1.1 Difficulties in forecasting and predicting flash floods

More specific difficulties in dealing with flash floods were observed in 2005 when the Environment Agency had to respond to the intense rainfall and flash flood in upper

Ryedale. Both spokesmen from the Environment Agency noted that the forecast data received from the U.K. Met Office was not of sufficient quality: a prediction had been made of a moderate amount of rainfall on the evening of the 19th June 2005 (an accumulation of ten to fifteen millimetres in one hour), as well as a chance of thunderstorm activity somewhere in the north of England. When heavy downpours began to the west of the upper Rye catchment, the Environment Agency found out about this through alerts from telemetry in the area, and the Agency also received telephone calls to Floodline from members of the public living in upper Ryedale during the flood. Therefore the Environment Agency was forced into a 'reactive' role to the heavy rainfall and flood event:

> ...all we could do was issue a flood watch which is obviously for low lying flooding of… well low lying land flooding and fairly low impact, but because there are no specific flood warning areas for these places that flooded, that’s all we could do. So it’s a lot more… and because of the nature of the flood as well it was all reactive rather than the normal proactive approach we take.
>
> EA Interviewee 2

6.1.2 Responsibilities for flood response

A second important difficulty in responding to the 2005 flash flood was revealed in the immediate aftermath of the flood. Significant damage had occurred in the area at, and upstream of, Hawnby (Figure 6.1) in upper Ryedale. However, the Environment Agency did not actually have any legal responsibilities to help clean up in this area, as the River Rye above Hawnby does not constitute an assessed main river: the Environment Agency has powers to manage flood risks on watercourses that are main rivers (DEFRA, 2007). One spokesman from the Agency stated that, in most other streams, above main rivers, landowners have responsibilities for maintenance. This distribution of responsibilities for watercourse management has been found to cause difficulties in other areas of England following flood events (Douglas et al., 2010). In upper Ryedale, the Environment Agency became involved in clearing the large amount of debris and animal carcasses away from the River Rye and several of the small streams in the area. This was due to two sets of concerns: a) the amount of debris blocking channels, as more heavy rain was forecast later in the week after the flash flood, and b) the possible health hazard caused by the carcasses. The local authority also did not have the equipment required to clean up the debris, and there were also ongoing access issues due to bridge damage:

> ...Now the problem was that the local authorities a) don't have the equipment to get in there and b) it was damn hard to get the equipment in there because of the narrow roads in the area so… and the bridges had been destroyed.
>
> ...
>
> ...we realised that there was a big risk, because there was more rain forecast later on in the week. So we moved in with our equipment and did some cleaning up and so there's some pictures of that. And that was just an ongoing process you see for about a fortnight after.
>
> EA Interviewee 1

The council representative also revealed the considerable danger posed to operatives who were sent out to upper Ryedale at the time of the flood, due to fast-flowing streams and rivers, and a significant amount of debris (as well as damage to bridges). As a result, the District Council were unable to become as involved in the flood response as quickly as they wanted to, particularly in the upper Ryedale valley near Hawnby:

> You got health, major health and safety.
>
> *Yeah.*
>
> At that sort of event so all you can do is stand back and watch it happen really.
>
> RDC Interviewee

6.1.3 Difficulties in the local assessment of flood risk

Importantly, the Environment Agency spokesmen stated that the organisation had not assessed a major flood risk in Helmsley prior to the flash flood, with very little flood risk assessed for the River Rye itself. Minor tributaries constituted a source of potential flooding, and the floodplain area in Helmsley was very small. Therefore, the installed rainfall and river gauging monitoring equipment in upper Ryedale was used for data input into forecasting models for areas lower down the catchment (most likely, Malton and the River Derwent lowlands), rather than for flood warnings. Therefore, the Environment Agency had not provided a flood warning for Helmsley and upper Ryedale. The Derwent Catchment Flood Management Plan (Environment Agency, 2007*a*) notes that flood warnings are not possible in some of the catchment uplands due to the flashy nature of the catchments (however, warnings are available for Pickering and Sinnington):

> "The nature of the catchment means it is possible to give our target warning time of at least two hours to most people at risk across the Derwent catchment. However, there are locations on the upper catchment where this could be improved or is not currently possible due to the quick response of the watercourses."
>
> Derwent Catchment Flood Management Plan
> Environment Agency 2007*a*: 13

Linked to this is a more general difficulty in establishing the floodplain area at risk of extreme floods, in order to produce flood risk mapping. One of the Environment Agency spokesmen pointed out the difficulty faced in providing estimates of the extent of extreme floods, particularly the 1 in 1,000 year flood outline which is required on flood risk maps:

...the Extreme Flood Outline and they remodelled it a little bit better and refined it a bit, but there's still issues with it and we've got a 100 year and a 1000 year outline now. **Because we have modelled and published a 1000 year flood outline then it was decided that we should expand our flood warning service to cover this theoretic risk.**

Right, okay, I see.

We would have been quite happy keeping it within reality and saying 100 year flood you know, but we've been working ever since in expanding the flood warnings service to cover the 1000 year outline as well.

EA Interviewee 1

The spokesman also noted the difficulty and inaccuracy of estimating flood risks in rural areas:

There is a suggestion that we should expand our flood warning service to cover agricultural land.

Yeah, you don't think it's possible?

There's a very rough ready and crude way of doing it but it's not very accurate and it will never be very accurate. It's very difficult to know every level of every field alongside every river.

Yeah, I see.

We'd rather concentrate on the domestic properties. But yes it's easier in the cities.

EA Interviewee 1

6.1.4 Monitoring and technology issues

Immediately prior to the 2005 flash flood event, the largest rainfall accumulations occurred in areas which were not covered by rain gauge monitoring (Wass et al., 2008, Table 1.2); and the rapid rate of river level rise during the flash flood was recorded at the Environment Agency's gauging station at Broadway Foot, located near Hawnby (Figure 1.2). However, this was interpreted as a technical fault rather than as a flood:

> ...you see on the graph like a rising level of floodwater and you get alarm levels and then it passes that threshold and you issue whatever you need to issue. But sometimes you see on the graph, you can see the river level going along and then spike going directly up that normally means that it's failed, so there's a technical fault on site and the centres failed, a vertical line means that. So I looked that day at these gauging station even though there weren't an alarm on it just to see what was happening and it was just ticking along nicely and then just went like that. So I thought oh well that's not working, I can't use that and it was the only reference point upstream of Helmsley. It turns out that the river level actually did do that and then went off the scale and washed away the gauging stations.
>
> EA Interviewee 2

A potential cause of this misinterpretation is the fact that the Broadway Foot gauging station had an ultrasonic gauge installed in 2003 (Centre for Ecology and Hydrology, 2011*a*), meaning that the measurement setup at the site was relatively new, and the Environment Agency staff would only have had limited experience of receiving this type of data from the gauging station. This misinterpretation also arose due to the nature of the river level-based flood warning system in England, which is not designed for flashy, sudden floods or floods caused by other mechanisms (Pitt, 2008; Twigger-Ross et al., 2009). At the time of research, there is currently no warning system in existence for flash flooding or other rainfall flooding, nationally (Coulthard et al., 2007; Cave et al., 2009; Coulthard and Frostick, 2010). Real time rainfall monitoring, as well as modelling of runoff, is required to provide effective warnings to flash floods (Gaume et al., 2004; Collier, 2007). The Environment Agency spokesmen interviewed pointed out the difficulties in providing flood warnings for upland areas:

> ...But yeah in terms of providing a warning service for somewhere like Helmsley, we're still not in a position to do that directly to people. And that is purely because by the time we know that there's going to be a problem it's very likely that we're not going to be able to get a warning out in time to them. Because what we don't want to do is call people when the flooding's occurring, because it's not providing a service. If we can't provide a lead time there's very little point in issuing a warning once a flood is already happening, if you see what I mean.
>
> EA Interviewee 2

The need for technological improvements to improve the forecasting of thunderstorms was further reinforced by the second Environment Agency spokesman. The unpredictability of the thunderstorms in 2005, the rapidity of their formation and their intensity have caused doubts over the ability of the Environment Agency to provide a lead time for warnings:

...The problem is detection and forecasting to start with and that's where we still have big issues with that. We are… before that flood of 2005 when the radar was developing and we thought that if we can get rid of… with the radar working really well, with a forecasting system on it we could actually set triggers and alarms on the forecast, on the weather radar which would then give us an early heads up if there's a lot of rain going to fall on a certain area. We could then feed that into our models and if it was going to cause flooding we could then issue a warning and we could get lead time, because we aim to give at least two hours notice of…on the warning system. So that was the plan but this flooding from 2005 is actually caused us to have some doubt about that, because this… these thunderstorms didn't develop, so… a long time, they were within an hour it had all developed and water… it had rained.

EA Interviewee 1

Despite advances in modelling, Collier (2007) viewed accurate flash flood predictions, with a lead time over one to two hours, as unlikely in the near future. However, lead times for flash flood forecasting have reached six hours (Hapuarachchi et al. 2011). In 2005, the first indications of an unusual event were picked up by the Environment Agency in the form of alarms on infrastructure in the Boroughbridge area to the west of upper Ryedale (Figure 6.1): the alarms were set off by the electrical storms which tracked over Thirsk (Figure 6.1) towards upper Ryedale. In addition, there was a recognition of the constraints faced by the Environment Agency to improve the flood warning systems, as one of the interviewees stated that, in Yorkshire, the Environment Agency personnel were limited to the responsibilities that they could cope with, and that they were (at the time of interview) at the limit of their capacity to provide telemetry. The Ryedale District Council representative also contrasted the predictability of lowland flooding of the River Derwent in the Malton area with the flash floods, due to the warning system (in Malton) and the fact that "...you could see it coming" as the river rose for a longer period of time. He suggested that, to deal with flash flooding, the Environment Agency's warning system was most important:

To, to have you got enough, it is probably a question you need to address to the Environment Agency.

Right.

Have they got enough time to warn people.

RDC Interviewee

6.2 Institutional responses to flash flooding

6.2.1 Rapid response catchments

An important factor leading to the recognition of the flash flood threat in the U.K. is the fact that the upper Ryedale flood occurred in the year directly after the major flash flooding in Boscastle, Cornwall (2004). The occurrence of two major flash floods, in areas with a low assessed flood risk, led to a national focus on identifying catchments where flash flood risks are high. As one of the Environment Agency respondents stated, the flash floods "...pushed the issue further" leading to a policy decision. The importance of identifying such 'rapid response catchments' was established in 2005 (DEFRA, 2005), and formed a research project within Making space for water (noted in Cave et al., 2009). Further modelling work (HR Wallingford, 2008) has also helped to identify areas at risk of flash flooding. The Pitt Review also made several references to rapid response catchments, identifying the need to improve local-scale forecasts and predictions of extreme rainfall

(Pitt, 2008). The rapid response catchment policy development was summarised by one of the Environment Agency representatives:

> ...we hadn't identified Boscastle that could be a problem there and we hadn't done that in Helmsley either. We identified that during normal fluvial events there wouldn't be really a flood risk. So looking at it purely from that type of extreme rainfall event, we started looking at identifying all those catchments and then looking at what people can do and the messages we can give them.
>
> EA Interviewee 2

A distinct characteristic of the rapid response catchment approach is that the focus is on the prevention of loss of life, rather than monetary damage. The Environment Agency defines a rapid response catchment as "A selection of rivers or streams that react rapidly to heavy rainfall, producing flooding that poses an extreme threat to life" (Cave et al., 2009: 8). This appears as a recognition of, and response to, the distinct characteristics and greater danger to life presented by flash flood events, in contrast to lowland floods (Gruntfest and Handmer, 2001; Ramsbottom et al., 2003). This risk to life characteristic was recognised by one of the Environment Agency interviewees:

> ...So the top ten rapid response catchments we've got in our area have looked at risk to life and the impact of that, rather than the traditional way of looking at justifying the flood defence scheme which is all about the economic impacts...
>
> EA Interviewee 2

The Environment Agency's approach to flood risk in rapid response catchments, and flash flooding in general, recognises the need to raise awareness of flash flooding and use local knowledge and involvement in the formulation of action plans and in the flood warning process (Cave et al., 2009). This approach therefore recognises the limitations of the existing flood warning system, with no system in existence for flash flood warnings (Cave et al., 2009), and the minor role which the Environment Agency can play in the warning process for flash floods (Section 6.1.4). As a part of the rapid response catchment approach, a focus is made on raising awareness among groups assessed as vulnerable to flooding, including tourists and occupiers of caravan sites in rural areas:

> It's that sort of thing that we're looking at, so where we've got summer campsites, we've… you get a lot of like CL caravan club sites for five caravans or ten caravans that spring up on farmers fields, the council has to give them a permit to operate, but we don't necessarily know about and what we'd like to do is get the council to have an obligation on them to say like, part of that application is, is it in a flood risk area and if it is what are you going to do about it.
>
> EA Interviewee 2

This specific approach to greater regulation of campsites is particularly relevant to the experience of flooding in upper Ryedale, as a number of motorcyclists at a campsite outside Helmsley narrowly escaped the flash flood event in 2005 (Wass et al., 2008; interviews); additionally, caravan sites have been viewed as being particularly vulnerable to flooding due to their physical nature and vulnerable populations (McEwen et al., 2002). Similarly, research into flooding case studies in Europe recommends targeted support for those living in vulnerable housing (Steinführer et al., 2009).

A further element of the rapid response catchments approach described was the formation of multi-agency flood plans (described in general in DEFRA, 2010; Section 2.4), mentioned by one of the Environment Agency interviewees. These aim to plan for future heavy rainfall and flash flood events, and define the actions and capability of the Environment Agency and other stakeholders. These plans are based on the previous experience of flash flooding, and one has been written for Helmsley:

> ...So what we have done though is for our highest priority risk areas like Helmsley and the Upper Rye catchment, we've started writing action plans to say what we've done since the flooding and what we're going to do and then also what our professional partners will do as well. So that's included in what we call the multi-agency flood plan now. So for Ryedale part of that multi-agency flood plan says what all the organisations will do in the event of another heavy rainfall.
>
> EA Interviewee 2

6.2.2 Engagement with local knowledge

In addition to the rapid response catchment policy change, the two Environment Agency spokesmen stated that, as an organisation, the Agency attempted to engage with local people and local knowledge more than they used to:

> ...In the past it used to be a kind of a process of deciding who's at flood risk and where, thinking what was the best scientific solution for it and going out and telling people what we were going to do. And I think people would assume that you can either turn round and go, oh brilliant you're going to do something for us, whereas it's sort of well you got that wrong. So we kind of learned from that and we go through this process now, it's called the Working with others process but basically what we do is the first round of any development work whether it's building new defences or offering flood warning services, meet the community, invite them to drop-in centres and ask them what their perceptions are of flood risk and what are the causes of flooding in their area.
>
> EA Interviewee 2

The former approach of the Environment Agency was more top-down and was described as less popular: the widespread Easter floods in 1998 (Horner and Walsh, 2000) seem to mark a change in Environment Agency policy towards the use of lay knowledge (Brown and Damery, 2002). However, interviewees in Helmsley described the Environment Agency as a remote organisation that was unaware of local concerns. In Helmsley, drop-in sessions after the 2005 flash flood were held, and such events were seen as beneficial by the Environment Agency for increasing local resilience. The spokesmens' responses showed some regard for local knowledge, as Helmsley residents had identified

Helmsley Bridge (and blockages at the bridge) as a cause of flooding, as had the Environment Agency's own modelling. Additionally, residents also appeared concerned about the lack of river maintenance, reflecting responses in interviews and questionnaires. However, importantly, both Environment Agency interviewees felt that local knowledge came with some caveats. They stated that there was a tendency for local people to be irrational, and 'shout and blame':

After every flood we get a mixture of emotions, we get anger just after, I understand it's a sort of way of healing, you know, that people want to shout and blame somebody and it's, you don't dredge the rivers or whatever, you know, it's always something like that.

EA Interviewee 1

...every time there is a major flood event we encounter what could be described as "local experts" with theories as to what caused the flooding - it's because you don't do this or somebody opened the valve on some reservoir upstream and caused the flooding, you know we've sacrificed Malton to save York* and all that… we've even had that.

EA Interviewee 1

*York and Malton are situated on different rivers, the River Ouse and the River Derwent respectively (Figure 6.1).

It is notable that aspects of the comments above were mentioned in some interviews with residents of upper Ryedale, and in received questionnaires. Some residents mentioned that they thought that the flood was caused, or worsened, by a dam burst in the upper catchment, despite this not being the case; river dredging was also a concern of residents. Furthermore, although not a comment made of upper Ryedale, one of the Environment Agency interviewees stated that sometimes residents were reluctant to tell the Environment Agency about past floods, as it was easier to tell the Agency that flooding hadn't happened recently. The implication made was that local residents would prefer to give the Agency the impression that floods were a new and recent problem:

...When you look back through the records and there's an issue of flooding in the 1800s (80s?), right though the early 1900s (90s?) and it has happened in people's living memory but they just chose to forget it and it's easier to tell us that it hasn't happened.

I see.

So yeah you... whatever you get told in drop-ins and stuff a lot of it is useful but you have to make sure you quantify it and clarify that it's fact.

EA Interviewee 2

Therefore, a need to clarify the information received from local residents was expressed. There are parallels with Environment Agency research into flash flood responses, which suggest that, while local knowledge is extremely important in flash flood responses, some local beliefs (including the perceived importance of river maintenance and drainage, and faith in structural measures to cope with flash flooding) do not accord with institutional views (Cave et al., 2009).

The Ryedale District Council interviewee was also asked about the Council’s use and uptake of local knowledge. While not stating that local knowledge was not used, the representative stated that the Council itself had knowledge and experience as a result of dealing with major floods in the past, and the council knew where flooding tended to occur and what to do about it. While not dismissing local knowledge completely, the representative clearly perceived that the council could cope with flooding issues without incorporating local knowledge:

I mean, do you get any feedback from local people passing on their own knowledge and experience of flooding to you? Does that help? Does that happen at all?

What we have, a good depth of knowledge and experience here.

Hum hum

In, in the organisation itself.

RDC Interviewee

6.2.3 Encouragement of local level resilience

One of the most important policies that the Environment Agency has with relation to flooding (at the time of research) is the encouragement of increased resilience and preparedness among members of the public at risk of flooding (e.g. DEFRA, 2005; policy background described in Section 1.3). As well as greater local awareness of flood risk, this also includes physical changes to properties, and individuals planning for actions to take when the river is rising. A role for insurance companies in the rebuilding of a property to a more flood-resilient standard rather than a simple rebuilding was encouraged. A summary of property-level mitigation was made by one interviewee:

> ...I mean yeah essentially it's about looking at your whole house and your whole property rather than just trying to keep water out, sometimes that's not feasible so what can you do to reduce the impact once it's in your home...
>
> EA Interviewee 2

The Environment Agency's approach of encouraging preparation among those at risk of flooding, was contrasted with the organisation’s traditional focus on flood warnings and their coverage:

> ...But a lot of our, sort of, work with communities to make sure they’re prepared for flooding. Like with the work… well what do they do once they get a flood warning, well we’ve always been measured as a business on how many properties are at risk from flooding versus how many we offer a warning.
>
> EA Interviewee 2

The Environment Agency spokesmen also appeared keen to raise awareness of flooding in the years immediately after a flood event, when memories of the event are still fresh:

Yeah the short-term has got to… well even with the long-term if that did become something you've still got to make sure that people in those areas know what the risk is and what they're going to do about it if it did happen and that's one of the biggest challenges really. And keeping that fresh, because you can set up a community flood plan after a flood and everyone is really keen to get involved, but then over a course of two or three years it just generally sits out of people's consciousness when other things, personal issues and everything else comes into play you know. It's difficult to keep that momentum going with it really.

EA Interviewee 2

Recommended resilience measures described by the Environment Agency interviewees included 'common sense' approaches, such as residents observing weather forecasts and acting on them, and also the use of flood boards:

...If you are aware that you are at risk from flash flooding then you should keep an eye on the local weather forecast and if heavy rain is predicted then take some precautions to protect your property.

EA Interviewee 1

Yeah, I mean I think what the Environment Agency do first is although we might not be able to offer a direct warning service, go out and provide help in terms of helping communities write flood plans, so that they know that if they hear on the weather for example that heavy thunderstorms are forecast for their area, they've got a simple list of actions they can take. Because for that sort of… for flash flooding the water's obviously up and down quite quickly, so flood boards and things like that across doorways are quite effective...

EA Interviewee

One of the Environment Agency representatives had a positive view of the existing resilience of local communities in rural areas. He said that they tended to be fairly resilient and often had their own coping strategies, without external input:

Well we also encourage resilience within the communities, you know, there's a bit effort going on to get communities to realise that they're at risk of flooding and to take action themselves and most of them are... they do realise that because they're in remote areas and so they're fairly resilient themselves...

EA Interviewee 1

The private resilience measures that were taken in Sinnington, a community in the Ryedale district which had experienced frequent minor flooding, were remarked upon in interviews. Some properties by the river in Sinnington had their own flood boards, and the main factor in this response, according to the Environment Agency, was the repetition of flooding in recent years and increased awareness of flood risk as a result:

> People that flood regularly are not a problem to us in the sense that they are well aware of the risk. They know... they often know the level on the gauge that causes their flood and so they can take action themselves and we give them the heads up for them to take action.
>
> EA Interviewee 1

Additionally, when asked about factors which influenced individual, private responses to flooding (or the use of private resilience measures), one of the Environment Agency interviewees implied that the perceived one-off nature of a flash flood, in an area without a history of recent flooding, will prevent individuals from taking action:

> *And (people) haven't experienced it (flooding) before and that's the main reason why they don't (protect their homes)...*
>
> Exactly yeah. Because quite often, you know, like at Boscastle or Helmsley is such a low probability of it happening, yeah it's very likely it hasn't happened before.
>
> EA Interviewee 2

Therefore, there is a clear link between this viewpoint and the lack of physical responses in upper Ryedale to flash flooding, as many interviewed residents stated that the flash flood was a one-off event and would not, in their view, happen again. Increases in resilience to flooding may not occur in areas that have experienced floods which are perceived locally as 'one-off' events.

Another factor perceived by the Environment Agency as affecting individual flood responses was finance, or the amount of money which people have available to them to spend on flood resilience. An Environment Agency representative stated that a resident's past experience of flooding, and resulting perception, would influence the priority that he/she would place on spending money on flood resilience measures:

...I think it’s the cost of doing it when… if you haven’t flooded before like… and you’ve got a certain amount of money available to yourselves, are you going to spend on your family, your savings or you’re going to spend it on planning for something that might never happen.

EA Interviewee 2

One of the Environment Agency interviewees described two other factors which influenced residents' willingness to increase their household’s resilience to flooding. The first of which was how practical residents were, and the extent to which they were capable of carrying out do-it-yourself measures. Secondly, the Environment Agency representative stated that some residents perceived that the Environment Agency should be responsible for flood protection:

...I think quite often people just don’t know that you can do those sort of things I think quite often and they assume it’s going to be expensive modifications to your home and it doesn’t have to be expensive, it can be D.I.Y options, you know, a whole range of things that you can do. Yeah, it’s difficult, everyone’s different really when you think of them, because obviously some people you see and they haven’t got a lot of money but they just do it because they’re very pragmatic practical people. Some people just take a totally different attitude to it and think it's someone else’s job to protect them or don’t want to do anything about it or whatever.

EA Interviewee 2

The support for resilience measures by the Environment Agency was therefore clear. It was explained that the Environment Agency's official objectives lay elsewhere in the maintenance of flood defences and providing flood warnings, and that the Environment Agency could do little aside from raising awareness in areas with no defences or warnings available:

> ...obviously our primary objective is to maintain and operate our existing flood defences and then issue flood warnings. So where we don't have flood defences and where we don't have flood warnings it's difficult for us to do much, apart from raise awareness and make sure people know what to do really.
>
> EA Interviewee 2

Similarly, the difficulty in providing a warning for flash flooding is another reason, in the view of one of the Environment Agency spokesmen, why residents should take action themselves to reduce their susceptibility to flood damage:

> ...we just haven't got the resources to go everywhere and help everyone, so people have to know what they're doing themselves, especially for rapid response flooding where we just can't get there in time to do anything about it.
>
> EA Interviewee 2

6.2.4 Improvements to forecasting data

Attempts have been made to improve the forecasting of flash floods and heavy rainstorms. At the time of interviews, the Environment Agency was receiving a greater amount of forecast information from the Met Office, including the receipt of low probability rainfall predictions in addition to the high probability predictions which the Agency had always received. An extreme rainfall alert service provided by the Flood Forecasting Centre provides alerts based on 10% and 20% probabilities of extreme rainfall (U.K. Meteorological Office and Environment Agency, 2009*a*). The Centre is a partnership between the Met Office and Environment Agency which became operational in April 2009 (U.K. Meteorological Office and Environment Agency, 2009*b*) and was established following a recommendation made in the Pitt Review, for the formation of the centre in order to improve the capacity to forecast for different types of flooding (Pitt, 2008: Recommendation 6). This recommendation followed widespread surface water flooding during the summer floods of 2007, particularly in Hull (Coulthard et al., 2007; Environment Agency, 2007*b*) (Figure 6.1). The Pitt Review also recommended that warnings should be provided by the Environment Agency and Met Office "...against a lower threshold of probability to increase preparation lead times for emergency responders" (Pitt, 2008: xxiv, Recommendation 34). Improved forecasting information is important for flash flood warnings, as the Environment Agency are able to change their operations with the receipt of such additional information:

> ...What we do now is we go right down to a 10% probability, so if there's a 10% chance of an extreme rainfall event occurring, they'll tell us about it and then it's up to us to decide what we do with that 10% probability of it happening. So most of the time it's just be aware of it and maybe put a standby rota in place just in case something happens. And then nearer the event they'll send updates on confidence and rainfall totals they're expecting. So we're a lot… we get a lot more information building up to an event like this in theory.
>
> EA Interviewee 2

6.2.5 Changes to land use management

The Environment Agency spokesmen were aware of work being undertaken in the Ryedale district to reduce flood risks in the Pickering area using changes to upland land use. Following a large number of floods, interdisciplinary research in Pickering (including modelling and the use of local knowledge) has suggested that some changes to land use (including the upland storage of floodwaters, and increased maintenance of vegetation and sediment in rivers and streams) potentially affects flood risks (Ryedale Flood Research Group, 2008*a*). Following on from these research recommendations, a two year project involving a number of environmental and academic stakeholders entitled 'Slowing The Flow' began in April 2009, assessing the potential for land use management above Pickering and Sinnington (Figure 6.1) to reduce flooding in these areas (Environment

Agency, 2010). In particular, the use of bunds to retain water in upland areas (above major settlements) after heavy rainfall are planned (Environment Agency, 2010). This technique was recommended by the Ryedale Flood Research Group (2008*a*). The impacts of land use management upon flood risks, and the need to use such management to prepare for flood risks in the future, are widely accepted (O'Connell et al., 2007; Wheater and Evans, 2009), although the impact of land use upon river flows is greatest at smaller scales (Blöschl et al., 2007). The possibility for land use to reduce flood risk was commented on by the two Environment Agency interviewees. The view was expressed that land management changes may be an important method to prevent rapid runoff and damaging floods in upland areas:

...Trails have been conducted to determine the effects of land use in flood risk management and Pickering is one community where this is now being done. It won't solve the flood problem completely but should reduce the frequency of flooding in an area where conventional flood defence schemes are not cost effective. Time will tell!

EA Interviewee 1

...But yeah I mean it's a very… it's sort of hard just because of the lead time we've got and I mean where there's a big risk we could look at building flood defences and it could be on the list somewhere. But I think it's going to be more about these sort of longer-term like land management things that are going to help reduce the impact of flooding.

EA Interviewee 2

The cost of the 'Slowing The Flow' project (£700,000) (Environment Agency, 2010) was partly funded by local levy funding, where local authorities are able to raise money through council tax, in order to spend money on local issues. This is administered through Regional Flood Defence committees. This source of funding is particularly relevant for upland and rural areas that are otherwise unlikely to receive funding due to the low numbers of individuals and properties affected by, or at risk of, flooding in these areas: where flood management projects do not qualify for government funding, local levy funding can provide a source of funds (Environment Agency, 2011*e*). This fact was commented on by one of the interviewees from the Environment Agency; these considerations of land use and funding arrangements were regarded as clearly relevant for upland flooding, and therefore upland flash flooding. Meanwhile, larger lowland settlements may benefit more from flood defence, due to the far greater overall exposure to flooding:

> ...local levy money tends to be better for places where you get less benefits for building flood defences, so that tends to mean rural areas, upland areas benefit from the local levy programme because in the grand scheme of things we're looking at places like, for example, York, Boroughbridge, you know lots of properties, major infrastructure, lots of benefits from each county spent on flood defence. Somewhere like Sinnington generally four properties flood, a maximum of 60 properties, in the national list it's just so far down in terms of its ranking it would never attract funding from DEFRA, because there's so many other areas of the country that would get more benefits. So the local levy money helps places like that by… they don't necessarily get flood defences out of it, but they get things like the Slowing The Flow project to try and reduce the flooding.
>
> EA Interviewee 2

6.2.6 Changes to Environment Agency working patterns

Finally, there was some evidence that the Environment Agency staff had to change the way in which they worked as a result of changing flood patterns. One of the spokesmen had worked at the Environment Agency for 30 years, and had noticed a shift from a 'traditional flood season', where floods occurred primarily in the autumn and winter, to a modern period where several floods occurred in the summer, primarily due to thunderstorms. This meant that the flood duty officer has a year-round role, rather than a concentration of duty during the 'flood season'.

When I was first involved with flood defence and flooding management, we used to have what we called a flood season and it usually went from about September to April/May time. But nowadays you can't relax at all, when you are on duty as a flood duty officer for a week, we do one in eight weeks and you come on and you just can't relax in the summer because there's always going to be something could happen… countrywide there's never a month goes past without some thunderstorm, downpour or whatever somewhere in the country, somewhere is getting hit.

EA Interviewee 1

The view of changing rainfall patterns from the Environment Agency's perspective is also reflected in upper Ryedale rainfall records, which suggest an increase in heavy summer rainfall since the late 1990s (Section 4.1.3); additionally, a perception of an increase in heavy rainfall and summer rainfall totals exists among local residents (Section 4.4). The move away from a flood season was not only a result of recent summer flooding: major flooding in the late 1990s included the 1998 floods in England and Wales which occurred in spring (Horner and Walsh, 2000). However, a challenge in dealing with summer floods was expressed, as such floods tended to be more sporadic and unpredictable from the viewpoint of the Environment Agency:

... now we just see like sporadic flood events all over the year and actually August is one of the wetter months now. In terms of like flood events, August is quite a big month for flood events, right in the middle of the summer really, summer holidays.

EA Interviewee 2

The Environment Agency interviewees linked these changing patterns of flooding and heavy rainfall described above to climate change: both felt that there had been a recent increase in heavy thunderstorms in the summer. This view was supported by local rainfall statistics, as the 2000s period observed a number of wet summers (Section 4.1.1), some very high summer maximum daily falls (Section 4.1.2) and a much higher frequency of heavy rainfall events in summer, in comparison with earlier decades (Section 4.1.3, Table 4.4). Although there was a more apparent, medium-term increase in winter rainfalls from the mid-20th century onwards, the period of heavy summer rainfalls described above implies increased risks of flash flooding, due to the typical occurrence of flash floods and causative intense rainfall in summer (Merz and Blöschl, 2003). Furthermore, one Environment Agency interviewee mentioned that research from the Met Office and 'climate experts' was predicting more extreme summer weather, and mentioned floods in August that had occurred in the North Yorkshire region. The other Environment Agency spokesman clearly recognised an increase in summer thunderstorms:

Climate change is associated with these events, you know, and we've had quite a few really heavy thunderstorm type events in the summer.

Okay, so these summer thunderstorms being sort of more…

More frequent.

Common?

Yes they’ve always happened but they’re more frequent now.

EA Interviewee 1

6.3 Possibilities for flash flood warning systems in upland areas: a comparison of upper Ryedale and Sinnington

While it is noticeable that Helmsley (and upper Ryedale) did not have a Floodline warning system in place, the two Environment Agency interviewees mentioned that the community of Sinnington (Figures 6.1, 6.2), located 13 km to the east of Helmsley, had a radar-based flood warning system. The Environment Agency had worked with local authorities, including parish councils, in order to modify the warning system. The River Seven at Sinnington was known by the Environment Agency as a flashy catchment, as the longest guaranteed lead time for flood warnings at Sinnington was an hour. Following rainfall-runoff modelling in the catchment, the rainfall radar in the village had been used to enable early flood warnings, and the Environment Agency had worked closely with the parish council in order to define an acceptable warning threshold. This work was clearly associated with high awareness of flood risk among residents, and flood response plans had been produced in Sinnington (and also at Pickering (Figure 6.2)) by the local community and parish council. The area had experienced frequent flooding before, and residents of Sinnington had taken measures to make their properties more resilient:

> ...I mean that's a place (Sinnington) where we can only give them... we can only guarantee about an hour's lead time for flood risk there, but we can give up to four hours depending on how good the forecasts are on flooding. But we've worked with the parish council there to say... to a agree what the flood warning triggers are because we could set the threshold higher which would give them less lead time but it would be a more accurate warning. But they said no, reduce it down. So we did some work... we gave them a range of options to say, look back in time to say over the last five years this level would have meant 50 false warnings, this level would have meant 20 false warnings. So they went for about 50 false warnings in the last five years they felt was acceptable for the number of warnings that would have actually led on to flooding. So we've agreed with them what the warning trigger is, they've helped us identify what levels mean properties flood and things like that and there's four houses that flood regularly and they've all got flood defence sort of... like private defences in place to help protect themselves.
>
> EA Interviewee 2

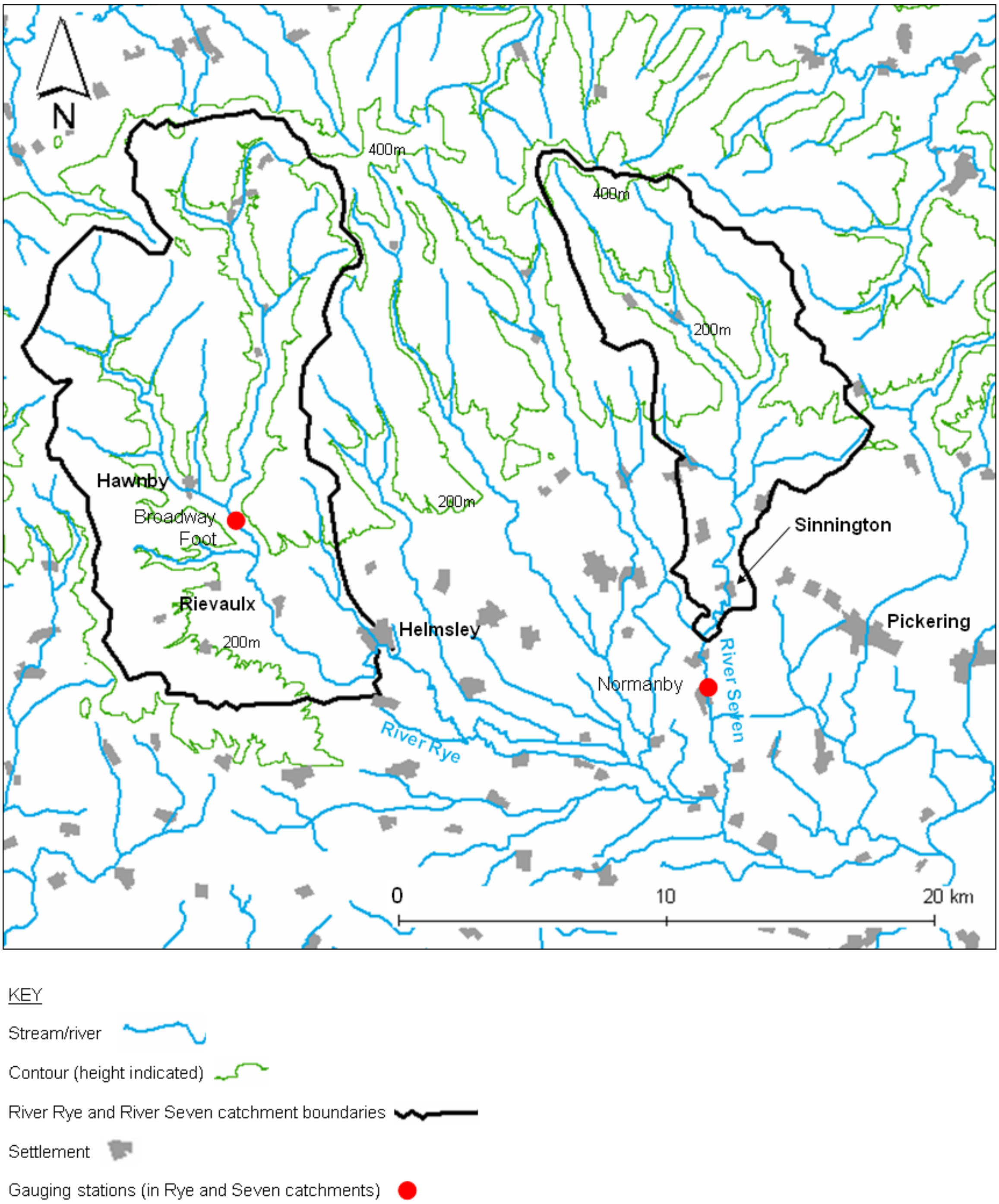


Figure 6.2: The upland River Rye and River Seven catchments above Helmsley and Sinnington (respectively), showing the gauging stations at Broadway Foot and Normanby.

Therefore, action from the Environment Agency had taken place, in an upland river catchment, to respond to the threat of flashy flooding. However this had resulted from frequent flooding, which had raised the perception of flood risk among both local residents and the Environment Agency, provoking responses to flooding from both groups. This was in contrast to the Helmsley and upper Ryedale area, where, despite the occurrence of a dramatic flash flood, a major view amongst affected residents was that the flood will not happen again, and responses have been relatively low as a result. The Environment Agency were also aware of the lack of major floods in upper Ryedale aside from 2005, and the lack of floods, in the words of the one of the spokesmen, "...in living memory":

> ...I seem to remember from the report that we had done… because we basically got consultants to come in and look at the flood history in the area for us and then model this event that we've had and try and quantify it in terms of probability and likelihood of another event. And there have been some reports of flooding in like… I think it was sort of late 1600s/1700s something like that, quite a long time ago, but they did find some records of it.
>
> EA Interviewee 2

Similarly, work and research to manage flood risk (the Slowing The Flow project) was taking place in the River Seven catchment, as well as above Pickering (Section 6.2.5), but not the River Rye catchment above Helmsley (Figure 6.2), potentially reflecting the higher priority of these catchments in the view of the Environment Agency. Therefore although actions had been taken to deal with flash floods, it appeared that there was some prioritising as to where they were implemented, based upon the frequency and recency of flood events. A comparison of the behaviour of the upper Rye and upper Seven catchments (Figure 6.2) during high flow events shows that, despite the exceptional flash flood in 2005 on the River Rye, the Seven catchment (where Sinnington is located) tends to experience much larger high flow events, when compared to mean discharge. The average peak discharge of a high flow event on the River Seven was 174% of the respective figure for high discharges on the River Rye (Table 6.1). Discharge also tends to increase faster during high flow events recorded on the River Seven (where the average discharge increase per hour during a high flow event is 4.3 times the mean flow), than on the River

Rye (average rate: 2.4 times the mean flow, per hour). The duration of discharge rises during high flow events is similar at both stations (Table 6.1).

Figure 6.3 shows the greater average peak discharges (and higher rates of discharge increase) recorded during high flow events on the River Seven, when compared with high flow events occurring on the River Rye. Therefore, the River Seven can be regarded as more 'flashy' than the River Rye, supporting the Environment Agency's decision to invest in a rainfall-based warning system at Sinnington, as well as the undertaking of a land management project (Slowing The Flow) in the River Seven catchment above Sinnington.

Flow record	Peak discharge (x mean flow)	Rate of discharge increase (x mean flow h^{-1})	Duration of discharge rise (h^{-1})
River Rye at	37.2	2.4	18.6
Broadway Foot	*10.7*	*1.4*	*11.6*
River Seven at	64.8	4.3	19.9
Normanby	*8.1*	*2.0*	*14.8*

Table 6.1: The characteristics of the 20 largest discharge events recorded on the upland rivers Rye and Seven, not including the largest discharge event (therefore, n = 19), 1978-2009. Peak discharges are shown as multiples of the long-term (1978-2008) mean flows recorded on both rivers (Rye 2.31 m^3 s^{-1}, Seven 1.94 m^3 s^{-1}). These mean flows are derived from Centre for Ecology and Hydrology, 2011a (Rye) and Centre for Ecology and Hydrology, 2011b (Seven). Figures in normal type are means, figures in italics are standard deviations. Discharge data provided by the Environment Agency, except 19th June 2005 peak discharge (estimate by Wass et al., 2008). Gauging stations at Broadway Foot and Normanby are shown on Figure 6.2.

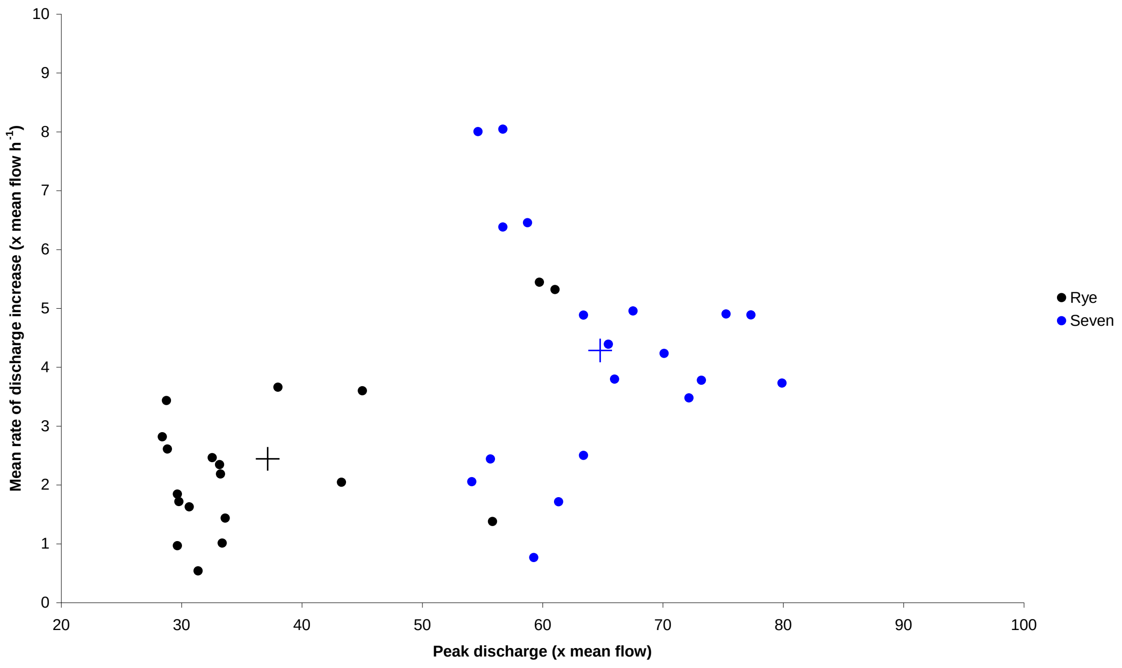


Figure 6.3: Comparison of the 20 largest discharge events recorded on the River Rye at Broadway Foot, and the River Seven at Normanby (shown on Figure 6.2). The events shown are those described in Table 6.1, minus the largest discharge event recorded at each station, with mean centroids shown as crosses. Not all events are shown. Discharge data provided by the Environment Agency.

6.4 Comparison of institutional viewpoints with local knowledge

6.4.1 Similarities between institutional and local viewpoints

The Environment Agency interviewees made several statements which broadly reflected some of the findings from the interviews with residents. The spokesmen believed that resilience, in the form of household-level responses to flooding, was an important factor in flash flood responses and also viewed rural residents as resilient people. Among those residents who were affected by the 2005 flash flood, a number of behavioural adaptations had been made after the flood, including increased awareness of heavy rainfall events and rising river levels, and response plans to deal with them (e.g. 'panic levels'); additionally, some (more limited) physical responses (e.g. building modifications) to flooding were made. As these responses had been made without the presence of long-term Environment Agency help, or improvements to flood defences or warning systems, it was clear that the local people had been able to adapt and make some alterations following the flash flood. Furthermore, it was clear that the main source of flood warnings in Helmsley, in the absence of 'official' warnings, was word of mouth communication from other residents who alerted friends and neighbours of the rise in floodwaters, an example of an 'unofficial' flood warning system based upon observations, communications with neighbours or friends, and resulting preparatory actions (Parker and Handmer, 1998). Creutin et al. (2009) noted that observations of river levels predominate as a spur of action in smaller catchments, rather than information received from other sources. Further to this, some residents remarked upon the loss of telephone communications during and after the 2005 event, which could have been used by settlements in the upper valley to warn the population of Helmsley about the flash flood. The Environment Agency view of the resilience of rural communities was also reinforced by the immediate response to the flash flood by the more remote community of Hawnby in upper Ryedale. Following the flash flood, despite infrastructure and communication damage meaning that outside help was slow to arrive, the local residents and estate had begun the cleanup process well before any local authority help arrived, as one resident of Hawnby stated:

> No, I mean all the hard work had been done before they (the authorities) virtually got here. They brought us disinfectant to wash out and things like that but most of the people had already washed out and disinfected before they brought that it was… I mean them chaps over there, it got to 4 inches off their ceiling and that were on the Sunday night, by Monday night there was a fire in the chimney.

In addition, other residents flooded in 2005 clearly showed an ability to adapt and react to perceived flood risks without any institutional help. It is notable that the following individual had experienced flooding several times:

Are you aware of things like the Environment Agency's floodplain maps and the warning codes that get given during rainfall?

No. As I say, we look out there and see panic level, then we panic.

Another resident had an attitude of wanting to cope by himself during flooding:

Are you aware of any recommended actions that you should take during the flood, any advice from the Environment Agency or the council? Have you been given any information about what you should do when the flooding occurs?

No, no. When the flooding occurs you usually just look after yourself and your neighbours, if you can do. Not really, no. It's really just a matter of trying to make your house safe and that's it, and the people that's living there.

While some residents of upper Ryedale who were directly affected by flooding in 2005 have reacted to the flooding, it is notable that neither of the Environment Agency spokesmen, or the Ryedale District Council respondent, were aware of any resilience measures taken by local residents in Helmsley. However, resilience measures in Sinnington were well known by the Environment Agency interviewees and also commented on by the District Council interviewee.

Some similarities existed between institutional and local views of relative flood risks in the Ryedale region. Many residents, both in interviews and questionnaires, stated that they felt that upper Ryedale had a much lower flood risk than the lower catchment, and settlements such as Pickering. This mirrors the Environment Agency's lack of assessed river flood risk in Helmsley; similarly, both local residents and the Environment Agency were aware of the long time which had passed since the 'Great Flood' of the 18th century (flood referred to in Wass et al. (2008)). Additionally, several of the observations made by local residents about the mechanisms of the 2005 flash flood accorded well with the Environment Agency's views on local flooding, as well as the findings of research into the flood events (Wass et al., 2008). As well as accounts of the intensity of the rainfall, and rapid river level rise, local observations of the importance of 'debris dams' at bridges as a cause of higher water levels and flooding were made:

> ...but all it did was the water came off the hills, got caught up in little river beds, dragged all the rubbish down and it dammed up behind the back of footbridges and then it took that bridge out and you get to the next one, dammed up there, all this water just kept damming up and damming up and then here it got to the Church Bridge and once it finally knocked that down it came through as a “whoosh.”

One of the Environment Agency spokesmen stated that following feedback from residents of Helmsley, he was able to support the conclusions of flood modelling which suggested that the Helmsley flood was exacerbated by another factor. It seems that a blockage at Helmsley Bridge was this factor:

> ...we couldn’t put enough water down the system to give us a flood outline that we had basically. So we thought there must… something must have happened at this bridge and that was reflected in what people were saying in the town in the feedback. So it’s good to sort of correct what the models are saying with the sort of real life experience.
>
> *So have people noticed any kind of debris got stuck under the bridge then?*
>
> Yeah, I mean… everyone… a lot of people identified the bridge as being a reason for flooding in that event and we assumed the blockage there was causing the flooding as well.
>
> EA Interviewee 2

6.4.2 Differences between institutional and local viewpoints

It is clear that there were some differences between local and institutional views on flooding and flood management.

6.4.2.1 Views on the contributing factors to local flooding

The Environment Agency interviewees were keen to stress climate change as a major driver of flash flooding, and a cause of heavy, more intense summer rainfall events.

However, while many local residents mentioned an increase in heavy rainfall events, particularly in summer, they were keen to stress issues related to land use change as a cause of flooding. A central component of this was the poor maintenance of rivers and drains, partly as a result of changing patterns of river management. Some interviewees and questionnaire respondents named examples of floods and settlements, both locally and regionally, where, in their view, poor river maintenance and debris accumulation had caused flooding. While a broad perception existed that local rainfall had become more intense, interviewed residents tended to argue more strongly about the maintenance of rivers as a cause of flooding. For instance, one individual (who was flooded in 2005), stated that his partner had persuaded the Environment Agency to dredge the River Rye, and argued that there was a difference in opinion on the effectiveness of dredging between himself and the Environment Agency. Additionally, the interviewee criticised a perceived management focus upon protecting the environment:

> …The Environment Agency say dredging doesn't make any difference, but it does make a difference.
>
> ...
>
> ...I think one of the major problems that the Environmental Agency, and therefore the government can do something about is insist on keeping rivers clear, not just letting a tree fall in and cause a blockage. If you go further down, the willows are creeping right into the river. The water just doesn't… There has got to be more done. They talk about protecting the environment. I think protecting property and people are more important than a few fishes.

It is notable that the research into flooding in Pickering undertaken by the Ryedale Flood Research Group uncovered similar views about river maintenance (Ryedale Flood Research Group, 2008*a*), as well as photographic evidence of an apparent increase in vegetation around channels in the Vale of Pickering (Ryedale Flood Research Group, 2008*d*). However, one of the Environment Agency spokesmen pointed out that dredging was not used as a flood defence measure on main rivers. The interviewee went on to note the differing responsibilities for clearing debris from rivers, and stated that although the Environment Agency used to actively keep river banks clear, this had negative impacts upon downstream flood risk; also, ecological concerns did come into consideration. However he did not feel that debris in rivers was a flood risk:

...we would try and get a tree removed should I say from the middle of the river if it was blocking on a weir or on a bridge and causing a flood risk, although when it is stuck under a bridge it's technically the responsibility of the Highways department to remove it There are many issues with fallen trees in rivers - the tree doesn't belong to us so technically if it falls in the river we are supposed trace owner and say, move your tree from the river, it might be 20 miles upstream but in practice we will move obstructions that are causing a flood risk.

Yeah, that's the thing.

So, yes exactly and… but once we've taken it out ourselves we've got to leave it on the bank for the owner to come and collect because it's not our timber in theory, this is the legal side of it but we take a practical approach to this. If it's going to… if we think it's going to cause a flood risk we'll remove it, but we don't necessarily remove debris if there is no flood risk

Okay. I mean has this sort of management method always been the case or…?

Yes, flood risk is always our first consideration. In the past there may have been a tendency to move all vegetation from river banks but we have concerns for the environment and vegetation slowing down the passage of water may not be a bad thing in flood management terms as it stops floodwater rushing downstream. However it an understandable reaction for people to think that an overgrown river is going to cause flooding.

EA Interviewee 1

Similarly, in an earlier response, the interviewee had listed the accusation that the Environment Agency did not dredge the rivers as one of the typical "...shout and blame" reactions of residents following a flood. However, he stated that he had not heard this in Helmsley after the 2005 flood.

The second Environment Agency interviewee stated that river maintenance (with regards to flood risk) tended to be mainly a concern of landowners, rather than residents. He also stated his opinion that, in Helmsley, residents were not concerned about river maintenance due to the lack of recent flooding in the area. This constituted a clear contrast with Helmsley residents' views, as over a quarter of those in the questionnaire survey gave the maintenance of rivers and streams as a factor affecting flood risk in Ryedale (Table 5.15), and the concerns of residents living close to the River Rye about maintenance were clearly revealed in several interviews. The second interviewee from the Environment Agency was aware of the criticism related to river maintenance, also noted elsewhere (Bunyan and Britten, 2009) that the Agency was more concerned about ecology and the environment than flood risk. However, he stated that the Environment Agency did maintain rivers, "...just not as regularly as they (residents) want us to." He reiterated the view that dredging was not a desirable strategy to prevent flood risk:

...We'll go in and remove any obstacles that we deem to cause a flood risk, but generally… like we won't remove gravel shoals on a regular basis, we'll take them out when they causing a flood risk but generally dredging isn't a sustainable or cost effective option when it comes to maintenance for example. But a lot of people say that it is what we should be doing and we've got very good reasons for not doing it.

EA Interviewee 2

Following the summer floods in 2007, the Environment Agency responded to the issue of river maintenance by pointing out the reduction in dredging since the 1980s, as it tended not to increase channel capacity; similarly, the removal of weeds only had a small influence on flood risks (Environment Agency, 2007*b*). Furthermore, river maintenance tends to be prioritised in urban areas (Environment Agency, 2007*b*). Some dredging did occur on the River Rye at Helmsley after the 2005 flood. According to residents, this decision appeared to have been taken by the Environment Agency due to the risk of river bank erosion, rather than flood risk. Some concerns were raised that the dredging had increased the flood risk in Helmsley:

> Debris. They put it on the wrong side. There's none on this side. Instead of the water going over in the fields, if we get another flood it's all going to come to us. We will get flooded out. There's no doubt about it, we're going to get it. Nobody has thought about that.

Further, more minor differences in opinion between the Environment Agency and local residents are uncovered in discussions of other factors influencing flood risk. While some residents were concerned about new developments on floodplains, and increased surface runoff, one of the Environment Agency spokesmen stated that a major problem was, instead, existing properties:

> We've got a legacy, a history of properties that are built in the wrong place which we have to deal with...
>
> EA Interviewee 1

6.4.2.2 Views on the way in which institutions and local residents work together and communicate

The Environment Agency spokesmen stated that the organisation was keen to work with local people and use local knowledge, and had conducted a 'flood surgery' in Helmsley immediately after the flash flood. However, despite a policy of 'Working with others' (Section 6.2.2; Environment Agency, 2011*f*), two residents from Helmsley who had attended the flood surgery were unimpressed by the Environment Agency, stating that the Agency were unaware of the local area. The impression of the Environment Agency was one of a remote organisation, not understanding of local situations:

> They called an emergency meeting at our town hall two days later. This was when the police had evacuated quite a number of us from the houses, and I think the Environment Agency were there and Yorkshire Water were there, and they didn't have any of the local knowledge at their fingertips.

> The Environmental Agency, when they did come and talk after the flood, they actually had an old map. The map they had of Helmsley showed a gas works down there. Well, the gas works has been gone for twenty or more years, probably. That's the map they had. They had a pack. You got a pack from somewhere. When you showed the Environmental Agency, they didn't know anything about it. It's their pack. People who came from Leeds didn't know anything about it.

These interviewees were also highly critical of the flood warning system provided by the Environment Agency. The interviewees stated their belief that no co-ordinated system existed for flood warnings, and that the actual details of schemes were poorly implemented on the ground:

> I think there's a lot of things within the national scheme that they have this good idea, like when you phone Floodline, but when it actually comes to the actual functioning of it there's nothing there. There's lots of different things where it falls down when it actually comes to putting things up. They float these wonderful balloons but there's nobody there to hold the string. It just floats off.

Some residents also felt that authorities did not inform local residents of the nature of work being carried out in the catchment. In Rievaulx and Hawnby (Figure 6.1) the presence of some people in the area following the flood was noted. It is likely that they were carrying out a post-flood survey (as commented on by the Environment Agency interviewees); however, the resident felt that the outside agency should have communicated its aims:

> …Somebody came round, I don't know who it was, and they put some markers on the road and took some levels and that sort of thing, and that's about it, but they never got back to you about it. I think they were taking levels from that to your house, while the mark was still on the walls and things, but never, they never write back to you and say what they had been doing.

A further detail related to the 2005 flood was also commented upon. The Environment Agency had interpreted the rapid rise in discharge recorded at the Broadway Foot gauging station as a station fault, rather than a flood. However the residents knew about the gauging station breaking, and one view expressed was that in 2005 the Environment Agency had known that a flood was occurring, but could not get a warning out due to the poor system. There was an assumption made by local residents that flood warnings were available for the Helmsley area, despite this not being the case:

> There doesn’t seem to be any coordinated system, apart from phoning Floodline, which is absolutely useless. There doesn’t seem to be any coordinated system of letting people know. On the night of the flood, we know a farmer at Hawnby and he said he knew there was going to be a problem. His land line wouldn’t work because of the flood; he couldn’t get a mobile signal, so he couldn’t let anybody know. He could have phoned us or friends up the road to say there’s going to be a problem, but he couldn’t get through. The fact that the Environmental Agency said, when we spoke to them afterwards, ‘We knew when the level gauge ceased to function there was a problem.’ But they didn’t do anything about it. That’s the Environment Agency monitoring the levels of rivers, which should link into Floodline.

A further, related point was that some local residents felt that authorities did not take local knowledge into consideration. Two residents in Helmsley argued that older local residents had much useful knowledge about past flooding, described as 'folklore', but that it was often ignored by local authorities (the District Council) in planning considerations:

Male: ...I can't think of any places in Ryedale, or not in Helmsley, where the houses have been built on a floodplain, except the new estate that was built twenty years ago. That clearly floods. People talk about going ice skating on those fields. They are talking about building more residential housing on there. If they build houses on there, that's taking some water, but people talk about going ice skating there in their youth. They're talking about putting houses there now, so that's a potential problem for the future. It has not happened yet.

Female: I think planners and local authorities choose to disregard known folklore. If you talk (name), the butcher, who has grown up here, and his family were here, he knows which fields flood, but the authorities don't always listen to the sages of the community. It's the older people who could really tell you, and that information needs to be recorded before it's lost. When builders want to push through and get change of use of farmland to residential, it's amazing what can be conveniently pushed to one side, and local authorities are to blame because they need the money, and they will sell off things like playing fields for residential land because they need the money and they need the tit for tat. You know, 'We need a new sports hall or a new community centre,' and the builder says 'I will build that if you give me change of use on the agricultural land.'

Additionally, the view was expressed in the above interview that the knowledge which older residents possessed was poorly valued by other residents, and that there was a divide in attitudes (towards building a new car park near to the river Rye) between those residents (of Helmsley) who had lived in the area a long time, and those who had moved to the area more recently:

...The people who thought it was a good idea were the people in the higher end of town who weren't flooded. When we did start to get a petition together, it was all the people down here, the old people in Helmsley, who remembered the beautiful fields, the woods, and didn't want that concreted over. It's the newcomers who were quite happy to have it happen. It wouldn't affect them, you see.

6.4.2.3 Views on the perceived and actual responsibilities and resources of the local authorities and Environment Agency

The Environment Agency interviewees argued that, in areas without flood defences and flood warnings, there was little that the organisation could do. However, when asked, some residents felt that other authorities should take responsibility for dealing with local flood risks, to the extent that they felt the local authorities should be responsible for protecting their property:

Whose responsibility do you think it should be to protect the house against flooding?

I would say the local authority and then your landlord. I'm speaking as a tenant. If I owned the house, I would say it would be the local authority and myself. As a tenant, I'd say the local authority, the landlord, and then I do the best I can myself with getting stuff out the way if it happens.

Whose responsibility do you think it should be to prevent flood damage to this house? Do you think it should be yours? Do you think it should be yours? Do you think it should be (the) local authority's?

I think it should be the local authority, really?

Why would you say that?

It seems to me to be their responsibility.

Therefore, it appears that residents believed that such institutions were capable of doing much more than the institutions themselves believed they could do. Indeed, the Ryedale District Council representative interviewed stated that he believed that the Environment Agency were able to provide a flood warning (via Floodline) to people in upper Ryedale, when in reality this was not the case:

I think you'll find that, that they (Helmsley residents) are on the flood warning scheme aren't they? Anybody who's adjacent to a main river.

RDC Interviewee

Conversely, the Environment Agency spokesmen stated that, as an organisation, the Agency had a poor understanding and knowledge of the reasons why some residents sign up for warning services (Floodline) and make individual responses to flooding, and others do not:

But the 60% thereabouts steadfastly refused to sign up for it (Floodline).

Why is that do you think?

There has been a lot of research into why people will not acknowledge their flood risk and numerous methods have been tried to increase the sign up to the flood warning service. There are many theories as to why they won't.

EA Interviewee 1

I mean what sort of, you know, what makes somebody respond to a flood like that do you think and somebody else doesn't? I mean if that makes sense?

Yeah, I know exactly what you mean because we struggle with this a lot...

EA Interviewee 2

While some ideas of factors influencing responses to flooding were stated, including some accurate ones (including the repetition of flooding, and the perceived responsibility that a householder has for managing flood risks), the Environment Agency interviewees did not mention some of the factors associated with awareness of Environment Agency services found in the questionnaire survey of the wider population of Helmsley. In particular 'personal' variables associated with awareness of services (including age, residents living with families, direct involvement with cleaning up following the flood, and witnessing the flash flood) were not mentioned by the Environment Agency interviewees. Similarly, subtle local viewpoints (including business and crime concerns, and emotional worries about future flood risks) were not remarked upon.

6.4.2.4 Views on the factors constituting a flood risk

The Environment Agency interviewees described the rapid response catchments approach being based on the risk to life posed by floods in these areas, rather than the cost of damage. However, looking at the patterns of questionnaire responses and interviewee opinions, residents of upper Ryedale believed that flood risks are higher in Pickering and Sinnington than in Helmsley. When offering this opinion, one local resident was keen to stress the economic costs of flooding, rather than a threat to life:

> ...Pickering, which is only fifteen miles away, there are people there who have been flooded five times in six years, and you would be in despair. You can't get insurance and the houses are almost worthless.

6.5 Discussion and chapter summary

Institutional difficulties in responding to and managing upland flash flood events, as opposed to lowland flood incidents, were apparent from the viewpoint of the Environment Agency. In an 'ideal' situation (Figure 6.4), a location prone to flooding has an official assessment of flood risk and has a population who are aware of this flood risk, as well as being in receipt of official warnings (e.g. Floodline). In the event of heavy rainfall, the Environment Agency receives clear information on weather forecasts and data from its own hydrometric monitoring network, and is able to provide warnings to those at risk who can then respond to them to prevent or limit damages. The cleanup following the flood then involves local residents, emergency services and local authorities. However, in the case study of the 2005 flash flood event in upper Ryedale, the Environment Agency was unable to respond to the flood in this way for a number of reasons (Figure 6.5). These included a lack of assessed fluvial flood risk in the area, linked closely with a lack of recent local floods, and a higher incidence of flooding in other parts of the region. This meant that the Environment Agency was unable to provide a flood warning to local residents, and also that the perception of flood risk among local residents was low. During the rainfall event and flood, the difficulties in monitoring the extremely rapid response of the catchment to rainfall were exacerbated by the limitations of the Environment Agency's upland monitoring network (restricting both the quantity and quality of available information) and uncertainties in the interpretation of received data. The unavailability of official flood warnings, and generally poor flood preparedness of local residents, exacerbated the damage caused by the flood (Figure 6.5). The Environment Agency was also involved in the cleanup following the flood, due to the severity of flood damages and impacts and the inability of the local authorities to respond to the situation. While the dangers of flash flood events are extremely apparent (e.g. Gruntfest and Handmer, 2001) the difficulties in responding to flash floods are also related to the limited ability of organisations to respond to them, as well as the dangerous characteristics of the floods themselves.

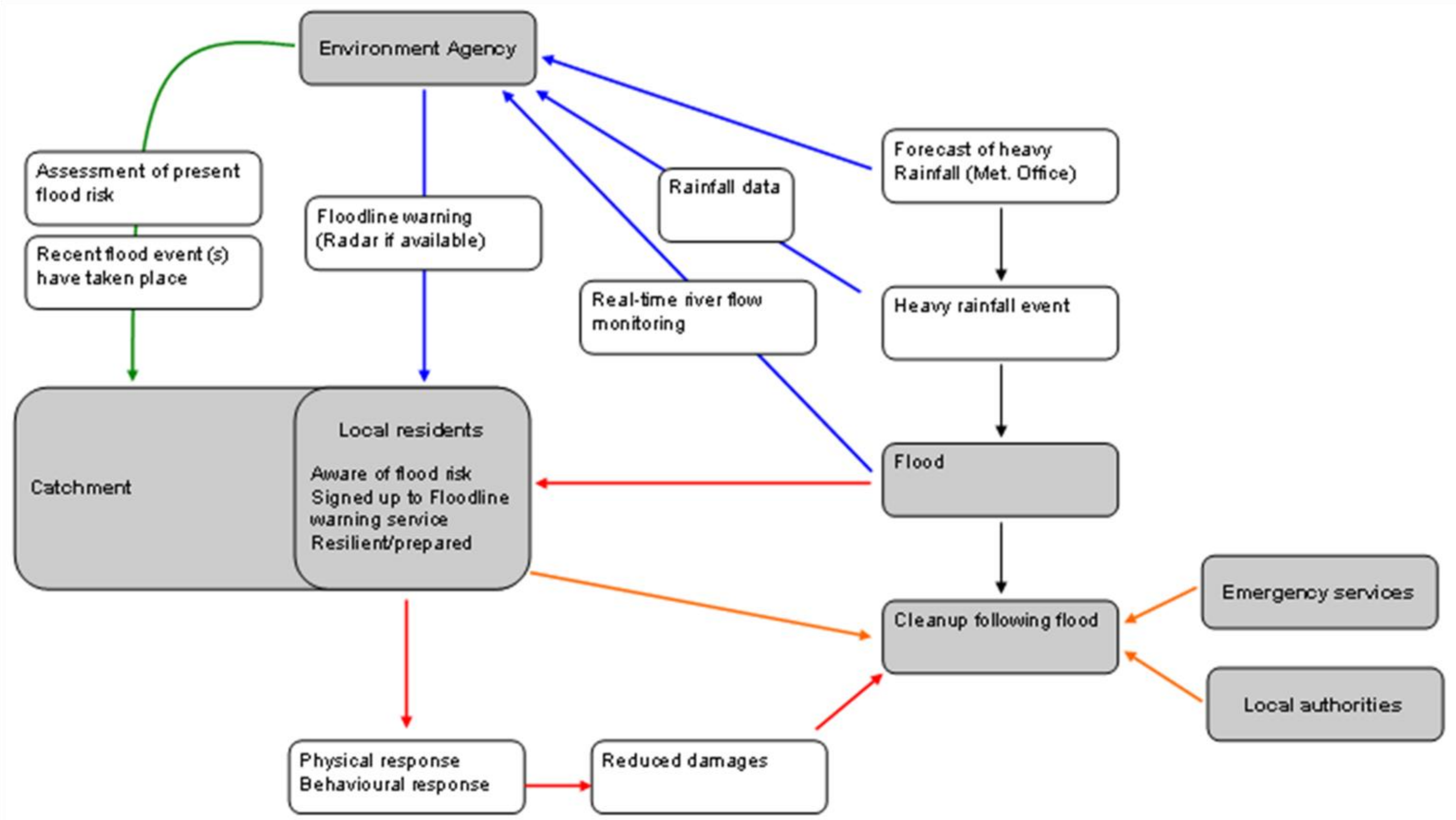


Figure 6.4: 'Ideal' framework for the response to, and management of a flood event, highlighting the roles of the Environment Agency and local residents. Green arrow shows risk assessment made by the Environment Agency prior to the flood. Blue arrows show the collection of technical data and information during flooding by the Environment Agency, and it issuing a flood warning. Red arrows show the flood event and the following flood response of local residents, and yellow arrows represent the cleanup following the flood event by local residents and other stakeholders. Diagram based upon institutional responsibilities of the Environment Agency (DEFRA, 2007) and information gathered in interviews.

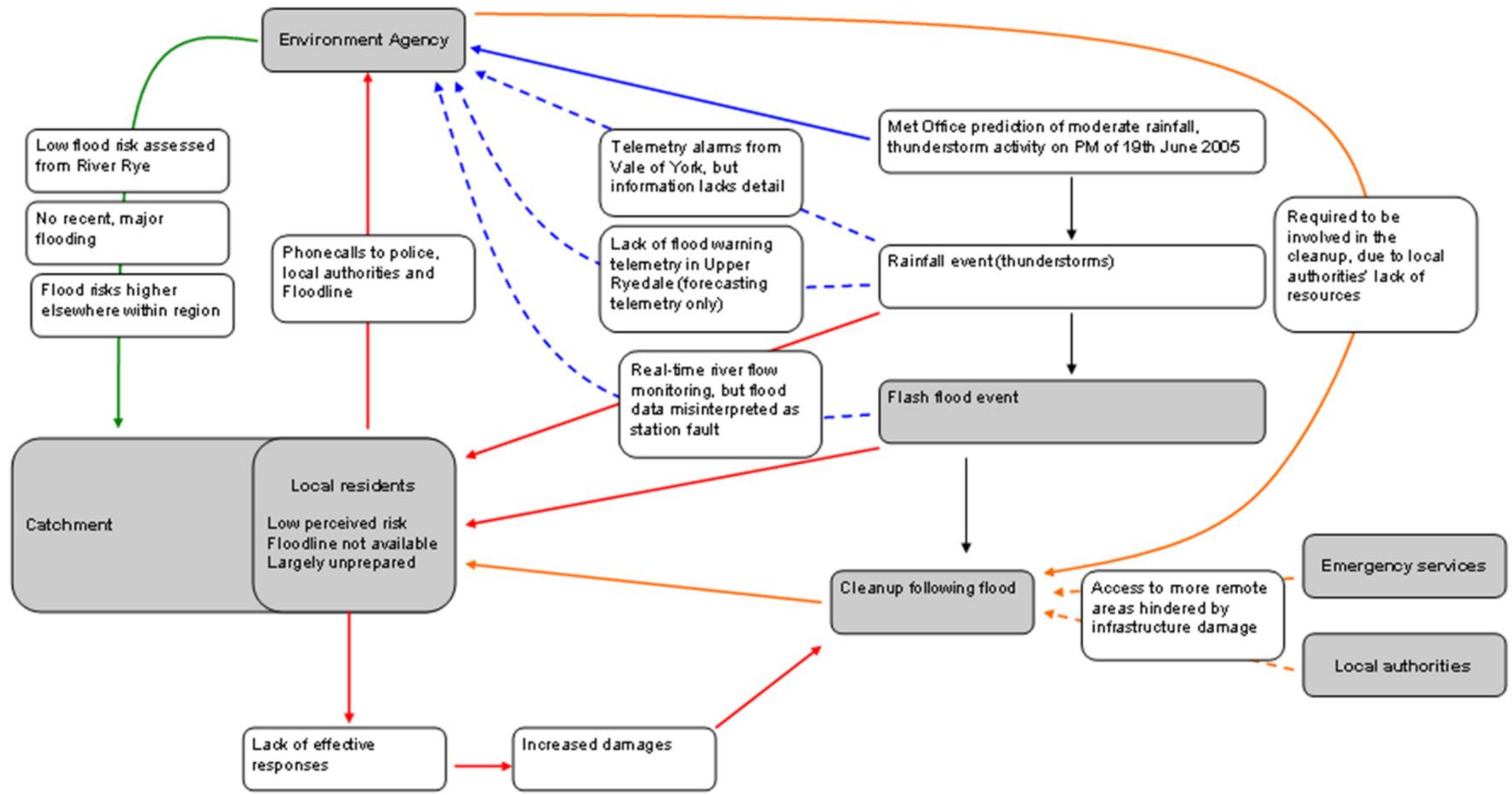


Figure 6.5: The response to, and management of the 2005 flash flood event in upper Ryedale, with arrows showing the passage of information and the involvement of different groups as in Figure 6.4 above. Broken blue arrows show information not being received or only partly received, other broken arrows indicate other difficulties. Diagram based upon institutional responsibilities of the Environment Agency (DEFRA, 2007), information gathered in interviews, and other thesis findings.

Therefore, policy changes to deal more effectively with the flash flood hazard were accelerated following the flash flood in Ryedale in 2005, as well as the earlier Boscastle flash flood of 2004. The focus on identifying and managing flooding in 'rapid response catchments' showed a recognition of the danger to life presented by flash floods (e.g. Gruntfest and Handmer, 2001), and the distinctive nature of the hazard compared with lowland flood events (e.g. Bronstert et al., 2002). The clustering of these major flash floods, and perception of a recent increase in heavy thunderstorms, led to a response. A number of researchers have commented on changes to flood policy and their drivers: in addition to a longer-term trend (in England and Wales) away from policies which favour land drainage and flood defence to those promoting flood risk management, major flood events have led to more rapid changes in flood policies (Tunstall et al., 2004; Johnson et al., 2005; Penning-Rowsell et al., 2006). Furthermore, public pressure for government response is often extremely strong after large floods (Parker, 2000; Samuels et al., 2006; Harries and Penning-Rowsell, 2011). Extreme events have been described as ‘focusing events’: that is, events which cause a major policy change (Lindquist, 2008). Additionally, flooding has been found to be a major driver of actions and adaptations to combat climate change in the U.K. (Tompkins et al., 2010). A good example of this was the passage of the Flood and Water Management Act (2010) (which occurred after the period of fieldwork for this thesis). Its provisions, including changes to the responsibilities of the Environment Agency and local authorities (Section 2.4) were strongly influenced by the recommendations of the Pitt Review following the major summer flooding of 2007 in England and Wales; changes to the Environment Agency's role (Pitt, 2008: Recommendation 2) and the local authorities’ role in the management of local flooding (Pitt, 2008: Recommendation 14) were included in the review.

The view that major flood events are instigators for policy change appears relevant here, as flash floods in Boscastle (Burt, 2005) and Ryedale and extensive summer flooding across England and Wales in 2007 (Marsh and Hannaford, 2007) led to reports and recommendations being produced by the Environment Agency (Environment Agency, 2007*b*; Cave et al., 2009) alongside reviews into the flooding (Pitt, 2008). These floods were particularly notable for a number of reasons: their timing (in summer) has been remarked upon as unusual, and not fitting with hydrological trends or predictions of future climate change (Marsh and Hannaford, 2007; Lane, 2008). Also, the mechanisms of these floods were unusual, as surface water flooding was the dominant cause of flooding in several areas, including Hull (Coulthard et al., 2007; Environment Agency, 2007*b*) (Figure 6.1). The fact that no national warning system exists for pluvial/surface water flooding is a particularly important fact highlighted from the experience of the 2007 floods (Coulthard et al., 2007; Coulthard and Frostick, 2010).

The Environment Agency have instigated a Flooding from Other Sources research project as part of the Making space for water strategy which looked specifically at pluvial flooding, surface water flooding, and flood events that occur in areas where flood risks had not been assessed (Hankin et al., 2008). Environment Agency reports have recognised the need for improvements to weather forecasting (including the formation of the joint forecasting centre with the Met Office), and an additional focus on improving local awareness of flood risks (particularly among vulnerable groups), as well as increasing the uptake of warning services and household resilience measures (Environment Agency, 2007*b*; Cave et al., 2009). Many of these strategies were mentioned by the Environment Agency spokesmen as being used in the Ryedale district. The strong influence of the Making space for water strategy (DEFRA, 2005) is apparent in the responses made by the Environment Agency to flash flooding, including the focus on increasing resilience and awareness, and the use of land use management is particularly notable in responses in Pickering and Sinnington. Similarly, the findings of the Pitt Review (Pitt, 2008) have been accepted by the Environment Agency, who mentioned the joint Environment Agency/Met Office forecasting centre, the need to improve warning systems for rapid onset and surface water flooding, the use of multi-agency planning and focus on increasing resilience and awareness, all implemented and relevant to flash flood management. However, in Helmsley and upper Ryedale, the institutional response to flooding was more limited, reflecting the relative rarity of flooding in this area. The experience of the nearby communities of Pickering and Sinnington has shown that the Environment Agency, in conjunction with local stakeholders as well as physical responses and considerable interest from local residents, was capable of making responses to upland floods and improving warning systems. However, as stated by the District Council representative, the recent flooding history of the wider region was one of widespread flooding in lowland areas, and frequent, relatively minor flooding in some higher altitude areas. Despite the extreme nature of the 2005 flash flood in upper Ryedale, the perception of the flood as a rare event by the Environment Agency and local authorities paralleled the view of the flood as a one-off event by many local residents (who often contrasted local flooding with more frequent flooding in other areas), and explained the greater action taken elsewhere. Encouraging responses to flash flooding is therefore extremely difficult with the dominant perception, among local residents, local authorities and institutions, that the event was a one-off and will not happen again, as preparedness arises from awareness of a risk and worry about that risk, leading to a demand to reduce the risk (Raaijmakers et al., 2008). In other parts of the region studied, local interest and flood hazard perception was higher in catchments which had experienced frequent floods (of both upland and lowland character).

The main difficulties in dealing with upland and rural flash floods, from institutional viewpoints, were seen as scientific and technical (in terms of assessing flood risks, forecasting, monitoring and flood warning processes), and also in producing adequate responses to flash floods in areas where major flood defences and capital spending were not viable. The Environment Agency's mapping and warning services, and the flood defences which they maintain, are solely designed for river and coastal flooding (Environment, Food and Rural Affairs Committee, 2008). It has also been recognised that funding schemes strongly favour urban, rather than rural areas (Johnson et al., 2007; Environment, Food and Rural Affairs Committee, 2008). Local levy funding was mentioned as a potential (smaller) source of funding within rural and upland areas; additionally, changes to the national funding approach after April 2012 (after the fieldwork for this thesis was completed) will "...value the protection of rural and urban areas on an equal like-for-like basis" (DEFRA, 2011*b*: 21). The limited role which the Environment Agency could play in flash flood responses in upland and rural areas was recognised by the Agency itself, therefore a focus was made on increasing both awareness of the flash flood hazard and household and individual level responses.

Changes to national flooding policies reflect the unsustainable nature of current policies, based upon predictions of increased flood damages in the future (Evans et al., 2004, 2008) and uncertain future flood risks (Kundzewicz et al., 2010; Merz et al., 2010). At the same time, the difficulties of preventing flood damages through traditional engineering solutions have been acknowledged (Institution of Civil Engineers, 2001), and the government has recognised the need to live with, rather than prevent, flood events (DEFRA, 2005). Flash floods, specifically, are an example of an intensive natural hazard (Burton et al., 1993) and a low probability, but high damage event, and strategies to increase resilience and reduce disaster potential have been argued to be the most favourable means to deal with such events (Klinke and Renn, 2001).

Regarding the upper Ryedale flash flood of 2005, the Environment Agency spokesmen argued that the organisation was more willing to engage with local knowledge and locally sourced information, however, some reservations were made about the accuracy of local knowledge and the validity of local views. Additionally, residents argued that the Environment Agency was a remote organisation which did not understand the local area, and that no system or organisation existed for translating outside programs and policies into effective ones ‘on the ground’. Similarly, Whatmore (2009) noted that those affected by flooding “...contest the expert knowledge claims and practices” (Whatmore, 2009: 594) related to flood risk management, with the common view that policies do not take into account of local areas and people. Such viewpoints have been found before: the research by Wynne into Cumbrian farmers affected by the Chernobyl incident told of farmers being angered at scientists’ lack of understanding of the worth of their specialist knowledge, and views that it did not need to be incorporated into wider scientific knowledge to manage an issue (Wynne, 1996). The lay views of “...ignorant and arrogant experts” (Wynne, 1996: 36) described in that study are similar to those of local residents encountered in this research, describing the Environment Agency. As well as concerns about not taking local views seriously, there was dissatisfaction with the Environment Agency’s provided services (including Floodline, and flood maps). Additionally, significant differences between local and institutional opinions existed with regards to the main factors influencing local flood risk: local residents were more likely to view river and drain management as a cause of local flooding than the Environment Agency, who viewed climate change as the primary cause of flash flood events. These views (particularly regarding river management) were particularly strongly held by many local residents, and have also been found in other studies following rural floods (e.g. Ryedale Flood Research Group, 2008*a*; Bunyan and Britten, 2009; Cave et al., 2009). Some research of flood perceptions has found that floods are "...often interpreted as the result of some human cause and if floods have not happened recently, this is because something has been done" (Green et al., 1991: 231); furthermore public views on the causes of flooding have been described in the literature as indicative of "...a very large gap between public perception and technical assessment" (Irish and Falconer, 1979: 329). More reasonably, the different viewpoints of the Environment Agency, and the public affected by flash flooding (related to the perception of the flash flood threat, and the causes of flooding) found in this study arise due to the fact that environmental issues "...are always made sense of or localised in the physical, social and cultural context in which individuals live, work and interact with others" (Bickerstaff and Walker, 2001: 143). Understandings of, and responses to, risk among the public arise in the context of everyday experiences, memories and judgement (Irwin et al., 1999). In the case of flash floods, the Environment Agency and the Government interpreted a growing threat of flash floods based upon evidence received, for instance the knowledge of a number of flood events (e.g. Section 1.1). However, at the local level, information, experience and knowledge of flooding was received in a different context. This reflects social constructionist positions and views of risk, which theorise that risks are only known “...through our specific location in a particular socio-cultural context”, therefore “...understandings and perceptions (of risk) often differ between actors who are located in different contexts and thus bring competing logics to bear upon risk” (Lupton, 1999: 30). Several residents expressed the belief that flash flood events were unusual and 'one-offs' rather than an increasing threat, and that rising flood risks were a result of poor river maintenance, rather than changes to climate. Such views are not ignorant, but are derived in a different context. Public views, in comparison with scientific or other authority views "...are not necessarily "incorrect" in their appraisals of the events; they pay attention to different characteristics and often deal quite differently with probabilities" (Burton et al., 1993: 111). The contrasts between public and Environment Agency views found in this research reflect closely the view of Irwin and colleagues:

> "From the expert perspective, lay reasoning about environmental and risk issues may appear to be ill informed or fallacious, and to include little distinction between what is relevant and what is not. From the lay perspective, meanwhile, the view of experts may appear to be unduly narrow and to ignore what, to the citizen, are crucial aspects of their everyday experience of environmental problems."
>
> Irwin et al., 1999: 1324.

From the Environment Agency's viewpoint, local views following floods tended to be typically emotional and of the 'shout and blame' type, and a need to clarify such views with further information was stated; furthermore, uncertainties as to the nature of local flood perceptions and responses to flooding were expressed. As the management of contextualised local knowledge and perceptions is important in flood risk management (Treby et al., 2006), a distrust of such knowledge is unhelpful. Some local residents pointed out that long-standing members of the community had a large amount of expertise about flooding and the local environment, and that they were being ignored. Research into responses to rural flash flooding in Italy has found that local knowledge has been slowly lost (De Marchi et al., 2007; Steinführer et al., 2009). Such knowledge is important in identifying danger within the environment and responding effectively: however due to the declining population in rural/mountainous areas, weakened community networks, and loss of contact between individuals, such information is declining (De Marchi et al., 2007; Steinführer et al., 2009). In this study, the view was expressed in one interview that the views and knowledge of long-standing residents should be recorded before it was lost.

Furthermore, local perceptions of rainfall change reflected some of the findings of analyses of long-term rainfall records (Section 4.4) and older residents had a good knowledge of different types of flooding in the area, and also knew of floods in the early part of the 20th century (Section 5.3.2, Figure 5.19) which occurred prior to river monitoring and were not recalled by the Environment Agency spokesmen or the District Council representative. While some members of the public have been found to have low awareness, or a straightforward denial of flooding and flood risk (e.g. Burningham et al., 2008) the Ryedale research experience showed that many residents were knowledgable and interested in these areas. Additionally, eyewitness observations of the Ryedale flash flood event proved helpful to the Environment Agency in the assessment of the event. Such local observations have been accepted as a very useful means of reconstructing flash flood events, when used in conjunction with collected rainfall and runoff data (Gaume et al., 2004; Borga et al., 2008; Marchi et al., 2009). These observations are particularly useful in areas where monitoring networks are sparse, such as upland areas (Macklin and Rumsby, 2007). Participatory research, incorporating local residents and their knowledge has been seen as having several advantages for hazard mitigation, including utilising more detailed and accurate knowledge of local situations, and the benefit that participation often leads to greater community support for measures taken (Wisner, 1995). The value of particularly knowledgable local residents has been recognised (McKechnie, 1996) and is reflected in the use of 'competency groups' for natural hazards research (e.g. Ryedale Flood Research Group, 2008*a*). The benefits of discussing risk perceptions, and the receipt of non-scientific information, has been recommended to the Environment Agency in the flood warnings field (Twigger-Ross et al., 2009). However, in this study, some interviewed residents felt that their views were not taken into consideration by outside agencies. From the viewpoint of organisations that manage environmental risks, such as the Environment

Agency, "...a key challenge is how to create an environment in which disagreements (between different sources of knowledge) are exposed and discussed constructively" (Failing et al., 2007: 55).

In interviews, a belief was expressed by the Environment Agency that rural residents were resilient: they could cope with adverse conditions well, without external assistance. Interviews with residents affected by flash flooding in 2005 supported this viewpoint: immediate responses to flash flooding in the more remote settlements in upper Ryedale were carried out largely without outside help. Similarly, evidence of behavioural changes following the flash flood event in 2005, including some private physical mitigation measures, suggested an existing level of resilience among some residents without input from the Environment Agency or local authorities. Given the difficulties in dealing with flash floods from an institutional viewpoint, this apparent existing resilience of residents in rural areas is a positive tenet, and is reflected in other research, which has found that in smaller catchment areas, communities and individuals tend to lead responses to flooding, rather than other institutions (Creutin et al., 2009). Upland communities in England are viewed by DEFRA as self-reliant (DEFRA, 2011*a*). Research conducted in Italian mountain communities exposed to flood and landslide risks has shown that the socio-economic context of remote communities (often with poor transport links, and situated a long distance from healthcare services) tends to encourage protective behaviour on account of a high perception of risk (often higher than the likelihood of hazards) and worry and fear about flooding, which drives perception and preparation (Miceli et al., 2008). Similarly, an analysis of European floods by Steinführer et al. (2009) found that communities with a strong attachment to a place cope better with flood threats, and tend to help themselves rather than expect help to be given to them. Uncertainty and worry about future flooding, when found in interviews conducted during this research, tended to be a driver of flood responses. Additionally, the belief in the resilience of people who live in rural areas may be linked to certain (stereotypical) personality traits of residents living there. An example is a person's 'locus of control': individuals with an 'internal' locus of control tend to believe that they control their lives, and are personally responsible for their successes and failures based on their own abilities. However those with an 'external' locus of control tend to believe that the direction of their lives is determined by fate or chance (Shaw et al., 2005). This aspect of an individual's personality has been found to be an important factor in the response to flood warnings (Mileti, 1995), as well as flood/hazard responses in general (Baumann and Sims, 1978; Tobin and Montz, 1997). Furthermore, the perception that government assistance following flooding will be inadequate has been linked to the purchase of flood insurance (Blanchard-Boehm et al., 2001). The link between personality and resilience is suggested by Armaş and Avram (2009) who argued that those with an internal locus of control tend to have a greatly reduced anxiety level. However, the ability of institutions (such as the Environment Agency) to respond to community needs following a local hazard, including the involvement of residents in decision making, is a further factor which influences the local response to a hazard, as well as the resilience of individuals and communities themselves (Rich et al., 1995).

In summary, the response to flash flooding in upper Ryedale was dominated by local- and household-scale responses, as detailed in Chapter 5. The Environment Agency and the District Council outlined several difficulties in dealing with flash floods: the Environment Agency in particular had to focus upon local resilience and awareness-raising due to its major responsibilities lying elsewhere (flood warnings and flood defences). Important differences between local and institutional viewpoints have been uncovered, and residents' perceptions of the Environment Agency, local authorities and their responsibilities differed from the views of these institutions. Institutional responses to flash flooding were also hindered by the need to respond to more frequent flooding in other parts of the region, and major lowland flood events, which appeared to take priority, and where flood risks were felt to be greater (by institutions, local authorities and residents themselves).

Chapter 7

Discussion

7.1 The wider context of flood risk management, and the upland flash flood hazard

It is important to place research into upland flash flooding into the wider context of flooding and flood management in England, which has undergone large changes during the 1990s and 2000s (Section 1.3). There has been a shift to a period of more frequent flooding (a ‘flood rich’ period, e.g. Lane (2008)) where the mechanisms of flooding are increasingly diverse, with a large number of localised events due to extreme rainfall (Section 1.1). Such events have often occurred outside the 'traditional' autumn and winter flood season, including major summer flash floods at Boscastle and upper Ryedale (Burt, 2005; Wass et al., 2008) and other events feature a strong surface water and pluvial component (for instance, flooding at Hull in 2007, e.g. Coulthard et al., (2007)). Furthermore, climate change may lead to an increased, but uncertain, flood threat in the U.K. (Wheater, 2006). There are large uncertainties as to predicting future changes in flood risk (Kundzewicz et al., 2010; Merz et al., 2010). As a result, there has been a questioning of the sustainability of existing flood management techniques in the face of likely future changes to climate and precipitation regimes (e.g. Brown and Damery, 2002), and a change to policies of flood risk management (e.g. Johnson et al., 2005), leading to an associated transfer of responsibility for flood adaptation and resilience to local areas and individual residents and households, reducing the government's responsibility for flood protection (Penning-Rowsell et al., 2006; Steinführer and Kuhlicke, 2007). The implication of this policy change can be summarised as follows: “...as all risk cannot be either avoided or managed, citizens should accept more personal responsibility for their decisions on where to live” (White et al., 2010: 338). Flash floods are one of a number of hazards which can affect upland areas; in addition, upland communities have particular, potential vulnerabilities (Section 1.2).

It is important to study responses to flash flooding, flood risk perception and the factors which influence them (Section 1.4). Flash floods require an understanding of perceptions, attitudes and awareness in order to adapt to the hazard which they present (Scolobig et al., 2009). The importance of personal attitudes, and engagement with social science research in attaining a greater understanding of flash floods is emphasised by Montz and Gruntfest (2002) who stated that advanced knowledge of hydrological and meteorological processes, and physical science "...will only make a difference if the recognition and understanding of warnings, warning response, and risk communication are increased" (Montz and Gruntfest, 2002: 19), similar views were also expressed by Drobot and Parker (2007). Improvements in the understanding of hazard perceptions and flash flood responses are extremely important given the rare nature of the flash flood hazard, which poses particular difficulties for effective preparation (Montz and Gruntfest, 2002).

7.2 Summary of responses to upland flash flooding by residents and the Environment Agency, and factors influencing them

This thesis has found a variety of responses among local residents directly affected by flash flooding (described within Chapter 5). There is a link between an individual's knowledge of the local environment (in terms of their knowledge and experience of flooding) and their response to a flash flood event. Modifications to make houses more resilient to flooding are generally concentrated among those who have experienced more than one flood event in the recent past. Other residents who had a different pattern of knowledge and/or experience of local flooding were strongly inclined to view the 2005 flash flood as a one-off event, or otherwise perceive the flood as unusual or rare. Indeed, somewhat counter-intuitively, questionnaire respondents who believed that the flash flood was a one-off event were more likely to live closer to the River Rye than those who did not believe that the flood was a one-off event. Respondents who were involved with the cleanup following the flash flood were more likely to agree that the flood was a one-off, and were more likely to disagree with the view that local flooding was getting worse, than those who were not involved with the cleanup. However, the questionnaire analysis also found that those respondents who believed that flooding of the River Rye (and surface water flooding) was getting worse recalled, on average, a higher number of recent floods than those who did not believe flooding was getting worse (such ‘floods’ may include very high river flows, associated with identified ‘possible overbank floods’ within this thesis (Section 5.4.4)). Therefore, an individual's knowledge of local flooding constituted a central influence on their perception of flood risk. In particular, if the character of local flooding is perceived to be frequent, and recently increasing, awareness of flood risks will increase and adaptations to flood risks are likely to occur. Other residents who perceive that floods are rarer, and in particular know of a) floods which were not flash floods, b) very large floods which occurred in the distant past, or c) no other floods apart from an extreme recent flood, are likely to perceive that local flood risks are not increasing and believe that major recent flash flood events are unlikely to reoccur. Case studies have shown that extreme flood events can lead to transformations in risk awareness and private flood preparedness, including changes in attitudes to flooding and increasing the motivation for mitigation, potentially leading to a reduction in damages (Kreibich et al., 2005; Kreibich and Thieken, 2009). Flash flooding, at a location which had not experienced recent, frequent flooding, did not have the same effect. A very large flash flood event is not, by itself, enough to provoke damage-reducing physical modifications against flooding; this constitutes a similar observation to that of De Marchi et al. (2007), who found that a flash flood event “...was not a catalyst for the adoption of household precautionary measures” (De Marchi et al., 2007: 76). There is a parallel with the observation by Weinstein (1989) that while experience of risks has important implications for risk perception, past experience with hazards can be complex, in terms of the nature of experience and its past frequency. A motivating factor for physical adaptations was concern over the risk of future flooding. Additionally, a number of attitudinal, financial and practical factors can reduce the likelihood of responses to flooding. Alternatively, changes to individual behaviour (including increased awareness of river levels and weather forecasts, and the placing of valuable items at elevated locations) were commonplace and appear to have arisen spontaneously among many residents; this independent action is positive and beneficial, and an increase in resilience to future floods.

Flash floods have markedly different characteristics to lowland floods (Bronstert et al., 2002; Bronstert, 2003) and it has been argued that flash floods “...should be considered as a specific category of disasters” to lowland river floods (Rosenthal and Bezuyen, 2000: 340). Although lowland flood events may lead to a large amount of damage, the threat to life posed by flash floods is very high (Gruntfest and Huber, 1991). This study has found that the different characteristics of flash flooding, in the context of an individual’s overall experience of flooding, strongly influences hazard perception in a different way to experience of frequent or lowland river flooding. The character of upland flash floods means that they are unlikely to be perceived as a genuine and serious threat in areas where they do not occur frequently; and while the awareness of the destructive threat which flash floods present increases considerably after such an event, the perception that such floods can occur again may not increase. The findings of this study in relation to flash floods are similar to the "...strong relationship ...between adoptions and frequency of hazard and especially the perceived frequency of hazard" described by Burton et al. (1968: 19). The strong influence of residents' flood knowledge and experience upon their perception of local flood risks found within this study supports these links.

The contrasts between perceptions and responses to the rare, extreme and dangerous upland flash flooding in upper Ryedale, and the views of residents living in nearby areas with frequent, moderate flooding (Pickering) are particularly notable: these types of floods are at different ends of the 'pervasive-intensive continuum' described by Burton et al. (1993). Similarly, conceptualisations of the factors influencing risk perception within the hazards literature have included 'situational factors' (Tobin and Montz, 1997) (Section 2.6, Figure 2.3) and 'Situation-related characteristics' and 'Risk characteristics' (Whyte, 1986) (Section 2.6, Table 2.2). Situational factors, including the "...physical characteristics of events", such as their magnitude, frequency and duration, "...help to define an individual's experience with hazards and shape perception" (quoted and adapted from Tobin and Montz, 1997: 150). The Ryedale Flood Research Group, which carried out research within Pickering, encountered "...a heated and controversial issue" (Ryedale Flood Research Group, 2008*a*: 6). A petition with over 4,000 signatures in support of a flood defence scheme in Pickering was sent to the (then) Government Floods Minister, Phil Woolas, in 2008 (Jeffels, 2008). This petition was noted in an (online) article published by the Gazette and Herald newspaper, which clearly recognised the salience of the flood issue in Pickering, resulting from recurrent flood events: the article used phrases including "...new worries for Pickering residents and businesses which narrowly escaped yet another flood this week" and flooding in 2007 was "...the latest of a chain of flooding incidents over the past eight years" (Jeffels, 2008). In 2009, the Member of Parliament for the (then) Vale of York constituency, Anne McIntosh, criticised the lack of flood grants for flood defences in settlements of North Yorkshire, including Pickering, Sinnington and Malton

(Jeffels, 2009), all settlements which have experienced frequent flooding. In a further newspaper article published about flooding in Pickering, Howard Keal, a flood campaigner stated that “People are absolutely desperate to see an end to the fear that has come into their lives” (Sutcliffe, 2007). Crucially, worry about risks is related to preparedness (Raaijmakers et al., 2008). Clearly, there is a much greater interest in flooding, and raised awareness of flood risks, in areas which have experienced a higher frequency of floods, which leads to an associated increase in preparedness among residents. Therefore, there is a link to the conceptualisation of preparedness made by Raaijmakers et al. (2008), which argues that preparedness for flood risk occurs when individuals are aware of the flood threat, and are worried about it. Raaijmakers et al. proposed a set of four typologies of risk, to describe an individual’s mindset, two of which are shown in Figure 7.1. Many interviewees from Helmsley and upper Ryedale, which had suffered flash flooding, showed a perception of risk that approximates the 'safety' characteristic: that is, they believed themselves to be safe, were not concerned or worried, and perceived the risk of flooding to be small and were thus relatively unprepared for the risk (Figure 7.1). Meanwhile, many residents of Pickering and Sinnington have a view which is represented well by the ‘risk reduction’ characteristic (Figure 7.1): they are aware of the local flood risk and are worried about it, to the extent that they have taken steps (in the form of some physical responses, such as household modifications) to respond to the flood. In addition, this concern and local interest has created a certain pressure and call for action in order to reduce the flood risk further, as evidenced by a demand for funding for flood defences. A few residents within Helmsley who had experienced multiple flooding also tended towards some aspects of the ‘risk reduction’ characteristic. These residents were concerned or uncertain about future flood risks in the area, and had taken some individual action(s) to prepare for future flooding.

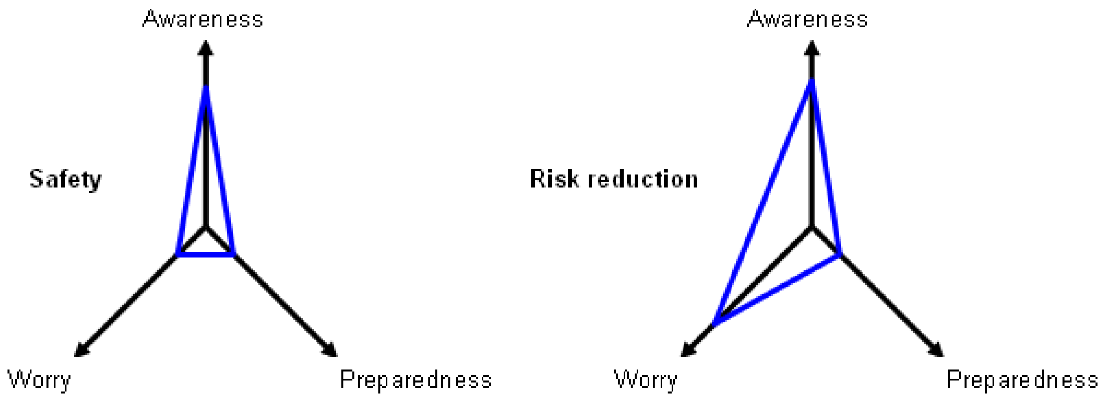


Figure 7.1: Radial diagrams showing two typologies of risk characteristics, as defined by Raaijmakers et al. (2008). The further the blue line is from the centre of the diagram, the higher awareness/worry/preparedness is. Diagram redrawn and adapted from figure 2 in Raaijmakers et al. (2008), page 313.

The contrast between upland flash floods and lowland floods has further key implications for the ability of institutions to respond to the flash flood threat. It has been noted that the Environment Agency's warning systems, and other provisions, "...are geared to river and coastal flooding only" (Environment, Food and Rural Affairs Committee, 2008: 10). The flood warning system is not designed for floods that occur suddenly and quickly (Pitt, 2008; Twigger-Ross et al., 2009) and this thesis has highlighted the inadequacy of monitoring systems, and transfers of information, during extreme upland flash flooding (Section 6.1.4). Furthermore, this thesis (Chapter 6) has found evidence of a lack of connectivity between the Environment Agency and upland communities. In this study, the Environment Agency's flood warning service was not available in the upland catchment, due to the lack of prior assessed flood risk in the area; furthermore, the Environment Agency did not have any responsibility for some of the upland reaches of the catchment as these areas were not designated main rivers, although a very large amount of damage occurred there during flash flooding. In England, the Government’s focus is very strongly upon managing river and coastal floods, rather than other types of flood (Environment, Food and Rural Affairs Committee, 2008). This thesis strongly supports the view that methods of managing lowland river floods are inadequate for flash floods (Associated Programme on Flood Management, 2007).

In reality, a number of factors govern the nature of the implementation of responses to flash flooding at the local level. A comparison of regional flooding suggests that other upland catchments have experienced a higher frequency of floods than in the study catchment (e.g. Ryedale Flood Research Group, 2008*b*,*c*). One settlement (Sinnington) has received a radar-based early warning scheme (Section 6.3), and the upland catchments above Sinnington and Pickering are undergoing a scheme to reduce flood risks using land management (Section 6.2.5). Therefore, certain areas which have experienced more recent and frequent flood events, and in which public perceptions of the flood hazard are stronger, appear to receive priority for these schemes. In addition, an analysis of discharge events suggests that high flows in the Sinnington catchment tend to be larger, and faster rising, than those in upper Ryedale (Section 6.3). The catchment of upper Ryedale, which saw one extremely large flash flash flood in 2005, rather than experiencing a higher frequency of floods overall, has not attracted these measures. Therefore, the markedly different patterns of flooding experienced in two neighbouring upland catchments have had several consequences. Firstly, there is a much greater interest in flooding, and raised awareness of flood risks, in the areas which have experienced more floods, which leads to an associated increase in preparedness among residents. Secondly, this local interest has created a certain pressure and call for action in order to reduce the flood risk. Thirdly, those living in other nearby areas are more likely to perceive flood risks where they live to be lower than those risks in areas where floods occur more frequently.

This study has identified a number of factors which are associated with the perception of local flash flood risks, as well as responses (behavioural and physical) to flash flooding, knowledge of which could benefit organisations attempting to increase local responses to flooding. However, some authors have argued that the abilities of institutions to 'educate' those at risk from natural hazards are limited, due to the nature of human perceptions and beliefs (Sims and Baumann, 1983); this being related to aspects of 'bounded rationality' (Simon, 1990). The uncertain and unpredictable nature of the upland flash flood hazard, and the implications that this has for local hazard perceptions, mean that communications with the public on the issue are potentially difficult. Slovic et al. (1981) summarise this issue clearly:

> "Despite good intentions, creating effective informational programmes may be quite difficult. Doing an adequate job means finding cogent ways of presenting complex technical material that is clouded by uncertainty and may be distorted by the listeners' preconceptions (and perhaps misconceptions) about the hazard and its consequences."
>
> Slovic et al., 1981: 29

While interviewed representatives from the Environment Agency spoke of raising awareness of flash flooding in catchments susceptible to flash floods, increasing engagement with local knowledge and encouraging household-level resilience (Section 6.2); the implementation of these policies is likely to be extremely difficult due to the characteristics of local perceptions and factors influencing responses to flash flooding (described within Sections 5.2, 5.3, Figure 5.20). In particular, knowledge of local flood events (and comparisons between local flooding patterns and those experienced regionally) is an important factor influencing perceptions. Additionally, a number of attitudinal, situational and economic factors influenced the likelihood of an individual taking physical damage-reduction measures, and demographic factors (age and house inhabitants) were associated with knowledge of the Environment Agency's services. Most importantly, experience of extreme flash flooding does not appear to be linked to increased perception of risk and damage-reducing responses to flooding.

There is an important contrast between local (public) and national (institutional) views, related to the perceived most important factors influencing flood risks. The Environment Agency strongly emphasised the importance of climate change, and its influence upon an increased frequency of heavy rainfall. Residents tend to believe that the local climate has changed, with a shift to more frequent and intense heavy rainfall, particularly in summer, a perception clearly well aligned with local records of heavy precipitation (Sections 4.1.2, 4.1.3). However, residents were most likely to mention local surface water flooding, including drain flooding, as being an important issue, and most respondents gave mixed to negative responses when asked whether flooding of the River Rye is getting worse. Local views of flood risks were supported by river flow records which emphasise the exceptional nature of the flash flood event.

Although residents perceived that increases in national flood risks had taken place, few linked this context with their local experience. Clearly, flash flood risks are difficult to perceive at the local level. The flash flood threat may be recognised by the government and relevant bodies, as a result of observations of flash flood events across the country (Boscastle, upper Ryedale) and observed and predicted changes to heavy rainfall (Section 2.2). However, in local areas affected by flash floods, such events are much rarer and are seen as unusual when they do occur, based upon the experience and knowledge of past flooding in the local area. This supports the findings of Bickerstaff and Walker (2001), who found that the public trust their own observations and experiences of environmental risks in preference to information provided to them; and also that while environmental issues are global ones, they "...are always made sense of or located in the physical, social and cultural context in which individuals live, work and interact with others" (Bickerstaff and Walker, 2001: 143). Krasovskaia et al. (2001) suggested that greater perceived risk among experts may result from their wider perspective. While the overall physical risk of upland flash flooding may be increasing, as a result of changes to the climate, the unpredictable and uneven nature of the way in which this risk increase is experienced in different locations across the U.K. leads to different changes in local perception.

Therefore, personal knowledge of flooding is an extremely important influence on flood hazard perception following flash flooding. Physical data analysis within this thesis (Chapter 4) suggests that the frequency of the heavy summer rainfall events which cause flash floods (e.g. Merz and Blöschl, 2003) has increased recently, alongside an increase in the magnitude of maximum summer daily rainfalls. In addition, extreme and intense summer rainfalls occur regularly in upland areas of the U.K., as evidenced by a number of upland floods in northern England (Duckworth and Seed, 1969; Carling, 1986; Harvey, 1986; Acreman, 1989; Cumberland and Westmorland Herald, 2007); in addition, the upland region of which upper Ryedale is part (the North York Moors) has recorded higher daily rainfall totals and also rainfalls of greater short-duration intensity than the 2005 rainstorm which caused flash flooding (Section 4.1.2, Figure 4.5). Over larger upland areas, flash floods caused by intense rainfall events are less rare than such events are at the local level. Carling (1986), providing references to written records, described "...a long tradition of exceptional upland Pennine floods" caused by thunderstorms (Carling, 1986: 105); also McEwen and Werritty (1988) stated that upland Scotland has a "...striking incidence of flash floods" primarily caused by summer storms (McEwen and Werritty, 1988: 361). Flash floods, however, are rare events at the local scale (Creutin and Borga, 2003; Borga et al., 2008) and flash floods do not occur after every upland heavy rainfall event. Therefore, there is a difficulty in perceiving the flash flood hazard at the local level: the rare, unpredictable and extreme nature of the hazard itself acts to reduce the probability of local responses to flash flooding. Additionally, evidence that the wider risk of flash flooding is increasing is unlikely to be perceived at the local level, even in upland areas where the risk of such events is greater. In addition, the low awareness of, and poor connectivity to, flood information services provided by national institutions discovered within this thesis means that the vulnerability to upland flash floods is raised.

Flash floods typically occur within summer as a result of intense rainfall (Merz and Blöschl, 2003) in contrast to major lowland floods, which are more likely to occur in autumn or winter as the result of prolonged rainfall (Bronstert et al., 2002). While projections of the future U.K. climate suggest an increase in winter heavy rainfall (e.g. Murphy et al., 2009), future changes to summer heavy rainfall, and therefore flash flood risks, are uncertain (Fowler and Wilby, 2010). While the dominant rainfall trend in the U.K. over the last 50 years has been an increase in heavy rainfall in winter (Section 2.2), precipitation patterns in upper Ryedale suggest a clear tendency for heavy summer rainfall events to be more extreme than those in other seasons (Section 4.1.2). The tendency for extreme rainfall events to occur most frequently in summer has been found in other U.K. studies (e.g. Hand et al., 2004) and is therefore a confirmation of existing knowledge. However an increase in these intense events suggests an increase in the risk of flash flooding, as the usual timing of flash floods and causative intense rainfalls is in summer (Merz and Blöschl, 2003). In upper Ryedale, summer rainfall totals, and heavy summer rainfall events, have increased from the 1990s to the 2000s, trends broadly reflected in long rainfall series from both the north-east region and England and Wales (Section 4.2). Additionally, discharge analysis (contained within Section 5.3.2) suggests that high flows in summer tend to rise more quickly than those in other seasons. High flows in winter, meanwhile, recorded on average lower peak discharges and rates of discharge increase than flow events in all other seasons. Within upper Ryedale, floods and ‘possible overbank floods’ are collectively strongly biased towards summer and autumn (Section 5.4.4).

An important issue which has arisen from this research is the recognition that some of the strongest arguments made by local residents tended to be about the issue of poor river and stream maintenance and its influence on local flood risks (Section 5.5). These arguments were found frequently throughout fieldwork, among both those residents directly affected by flash flooding and the wider population. Additionally, in upper Ryedale, public views of the services provided by the Environment Agency, including flood warning and information services, were predominantly negative. The public arguments related to river maintenance have been found throughout the U.K. (e.g. Werritty et al., 2007; Environment Agency, 2007*b*; Environment, Food and Rural Affairs Committee, 2008; Ryedale Flood Research Group, 2008*a*; Cave et al., 2009) and, similarly, research in England has found that flood victims have frequently made emotional and forceful arguments in favour of structural mitigation measures (Harries and Penning-Rowsell, 2011). For example, following the serious and widespread river flooding in Cockermouth and west Cumbria in 2009, local residents made a number of claims: that wildlife interests were being put before flood protection, that flood risks were higher because of a lack of river dredging, that river maintenance was much worse presently than it had been in the past, and that flood defence work was not proceeding quickly enough (Bunyan and Britten, 2009). Similar opinions were found in this research project, and would seem to be a common part of post-flood discourse in the U.K. There is strong evidence that, in upland areas, the aggradation of river channels and the deposition of large amounts of sediment can be an important cause of flood risks (Raven et al., 2009). The Environment Agency spokesmen interviewed in this research (Chapter 6) commented on their familiarity, and disagreement, with many of the arguments made by local residents, and mentioned the need to clarify such opinions. The Environment Agency spokesmen were, to some extent, dismissive of the accuracy of local viewpoints.

The U.K. Government, and Environment Agency, have recognised the threat posed by flash flooding to upland communities. However, this thesis has suggested that the implementation of policies and responses to flash flooding in reality is affected by a number of practical difficulties (Table 7.1). Differences in opinions between the Environment Agency and local residents, as well as negative views of each other, have been found in this research. Secondly, a number of Government and Environment Agency national policies have emphasised the importance of local involvement in decision making, and engagement with local communities. The Environment Agency spokesmen in this study explicitly mentioned a continued encouragement of local level resilience measures, the 'Working with others' process which has replaced earlier top-down approaches and utilises local knowledge, and also the need to raise awareness among groups who are vulnerable to flooding as part of the rapid response catchments approach. Increasing resilience and awareness of flooding are important aims of the Government’s flood policies (e.g. DEFRA, 2005; Section 1.3). Furthermore, the Environment Agency has recognised the difficulties of responding to local flash floods at the national level, due to technical limitations (forecasting) and the limitations of the Environment Agency's role, and acknowledges the need to manage flash flooding at the local level. Also, the Environment Agency interviewees admitted that they lack understanding of the ways in which the public act with regards to flooding, including the factors which lead local residents to use their information and warning services.

National policy change in response to flash flood threat	Difficulties in implementation, based on evidence from upper Ryedale
Identification of rapid response catchments (based on risk to life, attempts to raise awareness among vulnerable groups in these areas)	Residents most likely to view flood threat in terms of risk of property damage rather than danger to life
	Difficulty of raising awareness in areas at risk of flash flooding that have not experienced recent frequent flooding
Greater engagement with local knowledge (replacing earlier top-down approach, e.g. 'drop-in' sessions after flood)	Environment Agency spokesmen showed distrust of/disagreement with public opinions (particularly those related to river maintenance)
	Public perception that Environment Agency does not understand local concerns, and ignores 'folklore', particularly the knowledge of older residents
Encouragement of local level resilience (property-level adaptations and changes in behaviour in response to flooding)	Changes to property, spending money on increasing household resilience is unlikely given rarity of flash flood and low perception of future flood risk among many residents
	Local adaptation to flooding a result of a number of attitudinal and practical factors, poorly understood from Environment Agency viewpoint
	Belief among some residents that Environment Agency/local authorities should be responsible for flood risk management
Improvements to weather forecasting data	Provision of warnings based on forecasting are very difficult in several areas, particularly those where no prior flood risk has been assessed.
Changes to land use management (with other organisations and stakeholders)	Schemes are prioritised in upland catchments which have experienced more frequent flooding

Table 7.1: Summary of policy changes and responses by the Environment Agency to attempt to manage upland flash flood risks, and the limitations and difficulties in implementing them in upland areas, based upon information collected during this research. Table based upon research discussed within Chapters 5 and 6.

7.3 Contributions of this research towards upland flash flood mitigation and understanding

The link between upland hazards and changes to climate is highly important in the assessment of flash flood hazards. The nature of climate change makes adaptation difficult: it is a complex and slow process, but one which causes a higher frequency of extreme events (Burton et al., 1993). Rainfall studies have found larger increases in winter rainfall at upland (compared with lowland) stations in the U.K. (Burt and Holden, 2010); regional studies have also found that an increasing frequency of winter heavy rainfall in upland locations (Burt and Ferranti, 2012: northern England), and that the largest increases in heavy winter rainfall intensity have occurred at higher altitudes (Malby et al., 2007: Cumbria). Winter heavy rainfall in the U.K. has increased since the 1960s (e.g. Osborn and Hulme, 2002; Maraun et al., 2008). However, upland flash flood events show a tendency to occur predominantly in summer as a result of heavy and intense rainfall (e.g. Merz and Blöschl, 2003). Within this thesis, an analysis of a long upland rainfall series supports the tendency for heavy summer rainfall to be more extreme than rainfall which occurs in other seasons, and shows that in addition to a general increase in heavy rainfall since the 1960s, the 2000s decade has seen a period of wet summers, with a high frequency of heavy rainfall events in summer and large daily rainfall totals recorded in summer. Shorter-term increases in summer rainfall and summer heavy rainfall show rising upland flash flood risks. Evidence from this study (both maximum daily rainfalls, and notable heavy rainfalls recorded regionally) and other documented occurrences of upland flash floods in the U.K. (listed within Section 1.2), suggest that heavy rainfalls occur relatively regularly in upland areas, as do flash floods caused by heavy rainfalls at larger scales (Carling, 1986; McEwen and Werritty, 1988). Although flash floods may be perceived as rare and ‘one-off’ freakish events, the intense rainstorms that can cause them are not. Increases in heavy rainfall in upland areas are directly linked to other hazards: aggrading upland river reaches may be more sensitive to future climate change and experience a higher frequency of overbank flooding (Lane et al., 2007) and modelling suggests that increases in heavy rainfall (associated with land use changes) are linked to increased erosion of the drainage network and greater sediment yields in upland areas (Coulthard et al., 2000). Upland rivers are complicated and dynamic systems, and uncertainties imposed by climate change mean that the best management policy may be to simply live with the hazards (such as a flooding) presented by these rivers (Raven et al., 2010). There is a clear overlap with the wider ‘Making space for water’ strategy (DEFRA, 2005) and the recognition that “Floods can only be managed, not prevented, and the community must learn to live with rivers” (Institution of Civil Engineers, 2001: 73).

As a result of the high recent frequency of flooding (a ‘flood rich’ period (e.g. Lane (2008)) and the occurrence of widespread summer flooding and surface water flooding (e.g. Marsh and Hannaford, 2007), national policies to manage flooding have changed (Section 1.3). The important question ‘to what extent do such responses take into account of upland flash floods?’ arises. An analysis of two strategy documents, the first government response to Making space for water (DEFRA, 2005) and “Understanding the risks, empowering communities, building resilience: The national flood and coastal erosion risk management strategy for England” (presented to Parliament) (DEFRA, 2011*b*) shows that upland flash floods are scarcely mentioned. A search for the words ‘upland’ and ‘flash’ in the two documents finds few references: the word ‘upland’ is not mentioned at all in the 47 pages of the Making space for water response, although there was a mention of the Environment Agency’s role in “...compiling a register of catchments where the potential speed, depth and velocity of flooding would cause extreme risk to life” (DEFRA, 2005: 37) with the Environment Agency reviewing and changing “...its policies, processes and flood awareness information to ensure they are appropriate in those areas" (DEFRA, 2005: 37). In the 2011 strategy document there is a similar reference to the risk to life presented by floods of upland rivers (due to their deep and fast moving nature) and also a mention of land management options in upland areas to reduce the flood risk elsewhere (e.g. grip blocking, attempts to slow water) (DEFRA, 2011*b*). Similarly, the Pitt Review (Pitt, 2008) was carried out following major flooding in England and Wales in 2007, and the findings of this review influenced the Flood and Water Management Act (2010). However, the review did not explicitly respond to upland flash floods. The review did recognise that "...the greatest advances (in flood prediction and modelling) are needed in areas of greatest risk – significant depths and high velocities" (Pitt, 2008: xiii, also Recommendation 4). While the management of surface water flooding was a key component of the review, this was related to surface water flooding in lowland towns and cities (Pitt, 2008). Surface water flooding results from intense rainfall, but occurs due to poor drainage (Pitt, 2008), unlike upland fluvial floods that occur due to fast runoff (e.g. Bronstert et al., 2002). Making space for water and the Pitt Review both mentioned the ineffective nature of the flood warning system against flash floods, with the Pitt Review noting the unsuitability of the target two hour warning time as well as forecasting difficulties. Rural catchment management, and its role in reducing flood risks (by slowing the passage of floods and water retention, as well as rural land use management) is covered in the Pitt Review (Pitt, 2008) and managed realignment and rural land management form an important part of the Making space for water strategy (DEFRA, 2005). The latter strategy also states that "In the case of isolated or small rural communities, which are unlikely to benefit from a community scheme, building resilience or resistance may represent a key tool for managing their risk" (DEFRA, 2005: 23). The Government strategy document released in 2011 contains a similar sentiment: "Whilst the provision of major structural interventions to manage risk in rural areas may be less cost-effective than in more populated areas, the new approach to national funding will value the protection of rural and urban areas on an equal like-for-like basis" (DEFRA, 2011*b*: 21), referring to a change in the funding award system from April 2012 onwards. Similarly, the Pitt Review also received responses stating that a cost: benefit approach favoured urban rather than rural areas (Pitt, 2008).

While many of the responses of the Environment Agency stated over the course of this research: attempts to identify, and raise awareness in rapid response catchments, and land use management and floodwater storage schemes (as used in the North York Moors) are clearly directly relevant to upland catchments, the wider flood management policies implemented nationally (described within Section 1.3) are not primarily concerned with upland flash floods. As a further example, the Pitt Review's statement that "One powerful step the Government could take would be to significantly increase the take-up of flood warning schemes" (Pitt, 2008: xxxii) will simply not apply to several upland areas where flood warnings are not available. DEFRA's statement of its flood and coastal erosion risk management strategy, presented to Parliament (DEFRA, 2011*b*) identified a number of ways where those at risk of flooding "...should take responsibility for understanding the risks and, where appropriate, take steps to protect themselves and others" including "...signing up to the Environment Agency's flood warning system; ensuring that they have adequate insurance; preparing a flood plan for their household or business and preparing community flood action plans; creating or joining a local flood or coastal action group; taking steps to protect their property" (DEFRA, 2011*b*: 26). This strategy therefore makes an assumption that individuals are motivated to take such actions, and are aware and concerned of the risk of flooding. Increases in preparedness, and attempts to reduce risks, occur when a person is aware of a risk and worried about it (Raaijmakers et al., 2008) and hazard perceptions are an important explanatory factor of poor responses to hazards (Parker and Harding, 1979). In upland areas where major flash floods are viewed as one-off events, the perception of the flood risk may not be high enough to lead to responses, in particular the physical modifications to buildings which can greatly decrease the costs of flood damage (e.g. Thurston et al., 2008).

However, the Environment Agency does recognise the threat posed by upland flash floods. Spokesmen from the Agency clearly acknowledged the difficulties faced by it in responding to flash floods in rural and upland areas, compared with urban settlements in lowland areas subject to ‘traditional’ river flooding. For instance, upland telemetry, communication systems and the current flood warning system are not strong enough to offer meaningful flash flood warnings. These difficulties greatly reflect the two areas of uncertainty in flash flood understanding defined by Montz and Gruntfest (2002): physical science processes and characteristics of human response. The research report “Understanding of and response to severe flash flooding” was commissioned by the Environment Agency and produced in 2009 (Cave et al., 2009) as part of the Making space for water ‘rapid response catchments’ project.

The report made several recommendations to the Environment Agency which reflect a number of the findings presented in this thesis. It recommended, for instance, attempts to raise awareness that mention the need for residents to monitor weather forecasts and provide advice on actions after a warning is received, and also mentioned the importance of raising awareness due to the very short response time available. However, one recommendation clearly acknowledges the limitations of attempts by the Agency in educating and raising awareness among those at risk:

> "The Environment Agency should seek to take a measured approach to what may be achieved through public education and awareness-raising in the flood warning response field. It should certainly continue to engage in significant public flood education work, but it should also seek to manage the expectations of external parties and professional partners about the likely limitations of this approach and the impacts this will have during flood emergencies."
>
> Cave et al., 2009: 80 (Recommendation 22)

Also mentioned in the report are the importance of unofficial and self warning systems (including personal environmental monitoring), the importance of raising awareness among vulnerable residents (such as those living in campsites) and the need to use local knowledge (recommended at the local parish council level in rapid response catchments) to encourage responses to flash flooding (Cave et al., 2009). The report recommended that the Environment Agency "...should make available specialist resources to encourage community engagement in hazard mapping, local planning and flood response and awareness-raising" (Cave et al., 2009: 67, Recommendation 10). Following the report, the Environment Agency has been made aware of the distinct nature and threat of flash floods. However, the report recommended further research into perceptions and responses to flash flooding, in order to supplement understandings gained from the available literature. Therefore, this thesis represents a contribution towards this aim:

> "The research has relied heavily on an extensive literature review. Primary research has been limited by the timescale and budget for the project. Additional primary research, in the form of focus groups and telephone interviews, will be essential to building a more detailed and more representative picture of public and professional perceptions of flash flooding and the nature of particular vulnerabilities. It will also be crucial to developing interventions that support effective and appropriate response."
>
> Cave et al., 2009: vi

Within the flood risk management field, some authors have identified "...a big need for interdisciplinary and participatory research" (Mostert and Junier, 2009: 4979). This thesis has demonstrated the benefits of using an interdisciplinary research methodology, including the use of social science methods and research into human perceptions, in order to carry out research into responses to flash flooding. The need to incorporate social science methods into flash flood research arises from the fact that earth science based risk assessments only contribute expertise to one part of risk studies (Slaymaker, 1999), and the nature of flood risks, which are influenced by land use and socio-economic factors (Chang and Franczyk, 2008; Figure 2.1) in addition to physical characteristics and processes (Newson, 1994; Chang and Franczyk, 2008, Figure 2.1). Furthermore, interdisciplinary research is favoured due to the nature of the natural hazards framework, and its physical and social/human components (Section 3.2). The need to use an integrated approach to increase knowledge of both physical and social science aspects of the flash flood issue is extremely important (Montz and Gruntfest, 2002). In the model of vulnerability outlined by Cutter (1996), a location's vulnerability results from an interaction of physical and social vulnerabilities. This thesis has clearly demonstrated that the vulnerability of upland communities to flash flooding is more complex and multifaceted than analyses of physical datasets, and physical assessments of the flash flood risk can ascertain alone (Figure 7.2).

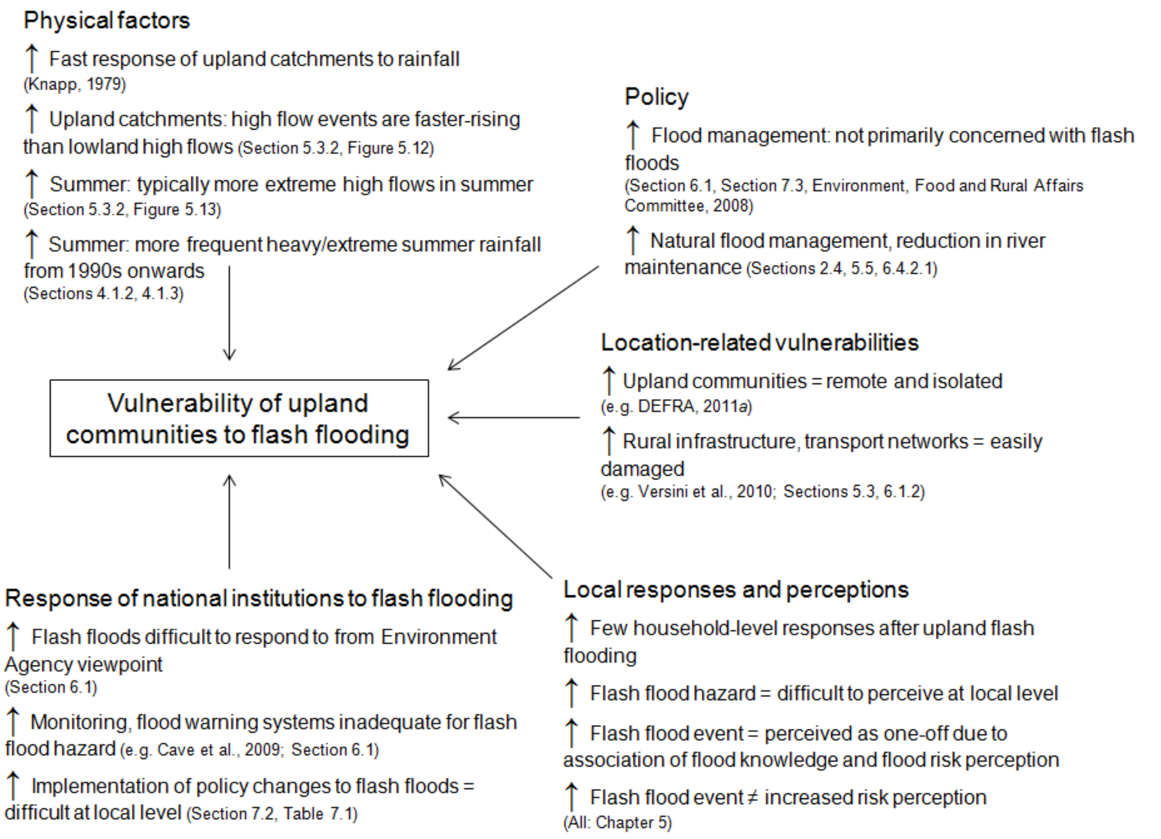


Figure 7.2: Factors influencing the vulnerability of upland communities to the flash flood hazard. Based upon literature review, and the findings of this thesis.

When describing the combination of quantitative and qualitative research methods, Bryman (1992) stated that “The researcher has to judge whether any important aspects of the research problem would be ignored if there was an exclusive reliance on one research approach” (Bryman 1992: 69). Clearly, if a solely physical and quantitative approach was used to assess flash flood risks, this would be the case. The vulnerability of upland communities to flash floods results from a combination of the physical hazard itself and several other factors (Figure 7.2). These other factors include human views and experiences (including perceptions of flash flooding, personal knowledge of flood events, other attitudes and viewpoints) and the nature of adaptations to the flash flood hazard (both physical and behavioural). In addition, the difficulties faced by institutions (the Environment Agency) in responding effectively to flash flooding, and the flood risk management policy context also have implications for the vulnerability of upland communities to flash flooding. This thesis has carried out research into fields within physical geography (the analysis of physical data to assess climatological and hydrological processes) and social science/human geography (hazard response, human perceptions and policy). As Douglas (1986) stated, "Increasingly, all available approaches, all possible lines of enquiry, all the evidence are needed to obtain adequate answers to complex geographical questions" (Douglas, 1986: 460). Similarly, Rhoten and Parker (2004) stated that "...scholars are confronted with questions that defy easy categorisation in or solution by traditional disciplinary frameworks" (Rhoten and Parker, 2004: 2046); and investigating responses to flash flooding is an example of one such question. The flash flood hazard, and indeed the flood hazard more broadly, may constitute an example of what has been termed a 'mess': a highly complex situation that cannot be 'solved' by identifying separate problems and solving them individually (Ackoff, 1974). The plethora of issues and questions related to flooding mean that it can be defined as a mess (Donaldson et al., 2010).

A key aim and process within interdisciplinary research is “...building workable bridges between otherwise compartmentalised knowledges” to improve understanding (Lau and Pasquini, 2008: 554). As a result of the exploration of a number of quantitative and qualitative datasets and information sources, incorporating methods from the social and physical sciences, this thesis has uncovered links between aspects of the physical environment and human perceptions and responses, which would not have been discovered using a pure physical geography research methodology. For instance, the character of residents’ knowledge and experience of flood events has a strong influence upon flash flood risk perceptions, and responses to flash flooding. Personal viewpoints of the local river environment, such as ‘worry levels’, have also been found, which play an important role in perceptions of, and responses to flooding. Following the flash flood, many residents observed river levels more frequently. Questionnaire analysis found statistically significant associations between residents' perceptions of changes to flooding and rainfall, and some types of responses to flash flooding. Expressed perceptions and opinions about flooding (such as the 'one-off' nature of flash flood events) have been 'tested' in this thesis with comparisons to analyses of river discharge records. Residents also linked changing rainfall patterns to flooding, at various scales. Clearly, local residents construct viewpoints of the physical environment through previous experience. Local residents' views of climate are formed using such mechanisms as "...experiences and memories of past weather events, and what is socially learned from previous generations" (Hulme et al., 2009: 198). Similarly, flood experience leads individuals to form a 'model' of flooding, and an estimation of future flood probabilities (Green et al., 1991). These aspects of human perceptions are examples of the construction of environmental issues within a local context (Irwin et al., 1999; Irwin, 2001; Bickerstaff and Walker, 2001). This thesis has found that these links between the physical environment and human viewpoints are in turn linked to responses to flash flooding, and an interdisciplinary research approach is clearly the most useful, and most appropriate, in discovering and assessing them. Notably, local residents' perceptions and viewpoints of changes to rainfall and flooding reflected the changes to heavy and seasonal rainfall, and the nature of high flow events revealed by analyses of physical data. The unusual form of the 2005 flash flood event, seasonal differences in flood risks, and changes to local rainfall patterns including recent increases in summer heavy rainfall have been discovered through both analyses of physical datasets and the viewpoints of local residents; additionally, differences in the frequency of flooding across the local region were clearly recognised by residents. Lane and colleagues (2011) found that residents' knowledge of local flooding in Pickering reflected the scientific understandings of flood processes and physical geography possessed by modellers (Lane et al., 2011). Within this study, recalled experiences with the local environment have much in common with the statistical analyses of rainfall and river flow data.

Risk perceptions are, by their nature, subjective (e.g. Mishra and Suar, 2007) and have been described as having “Judgemental biases” (Slovic et al., 1981: 17). However, the analysis of numeric data retrieved from the physical environment, and resultant findings, have important limitations in a study of flash floods. The speed of flash flood processes means that physical monitoring stations are unable to record them effectively (Creutin and Borga, 2003). The experience of the 19th June 2005 rainfall event emphasises the fact (also noted by Archer, 1992) that rain gauges are unable to record the extremes of localised heavy rainfall effectively (Wass et al., 2008). Similarly, estimated peak river flows can be uncertain (Shaw et al., 2011) and gauging stations can be bypassed during flooding (Newson, 1994). The 2005 flash flood event in upper Ryedale was not directly measured due to damage at the gauging station (Wass et al., 2008). Secondly, it can be argued that, by nature, data analysis is interpretive and “...ultimately all methods of data collection are analysed “qualitatively”” (Fielding and Fielding, 1986: 12). Within this research project, the researcher’s selection of the most appropriate methodologies to use, certain techniques in forming data series (including the process of filling in gaps in lengthy time series), and the identification of trends and patterns in quantitative analyses have had a clear subjective element to them. Thirdly, and most importantly, physical data series used (Section 3.7) are relatively short and discontinuous, and include some missing and/or low quality data. Therefore, personal memories and recollections of flooding and changes to rainfall, alongside documentary sources of information have been found to be extremely important sources of information about flooding, which are available for a longer time period in comparison to physical data series. This is particularly important in the case of the upland flash flood hazard, due to the fact that flash floods are often unrecorded (Marchi et al., 2010). The use of social science approaches and surveys to increase the understanding of flash floods have been recommended (Gruntfest, 2009), and "Eyewitness accounts fill in gaps where there are no instruments to detect flooding, and they provide more complete and richer pictures of all aspects of flash floods" (Gruntfest, 2009: 83-4); witness observations also can play a role in post-flash flood surveys (Gaume and Borga, 2008). During this research project, personal memories have been found to be more detailed than simple numerical values of daily rainfall or river flow, as recalled information about floods has contained information about the speed of past floods, the cause of flooding, flood extent as well as information about other types of flooding (surface water flooding and drain flooding) which are not monitored by discharge records. Personal communications have been noted as a possible method for learning about past flooding (McEwen, 1987); and historical flood information (more broadly) can add to the knowledge derived from flow records (Williams and Archer, 2002). Finally, this thesis has used the relationship between known high river flow events and assessed causative rainfall events to identify possible overbank flood events based upon daily rainfall data (Section 5.4). While the relationship between known high flow events and constructed possible overbank floods is moderate, possible overbank floods are associated with periods and years with above average heavy rainfall, and some possible floods have highlighted known flood events and very high recent discharge events which may be an influence on flood risk perception. They have emphasised the importance of summer as a key season for local upland flooding, and have also been assessed alongside floods recalled by local residents in interviews and questionnaires (Figure 5.19). The use of several methods to assess changes to flooding and rainfall patterns constitutes an example of triangulation, which is beneficial to research (Mathison, 1988) as are multi-method approaches more generally (Brewer and Hunter, 1989).

Furthermore, risk perception studies into flooding may benefit policy makers, as they can determine precautionary behaviour (such as household modifications) and can inform policy (Botzen et al., 2009). The management of hazards based upon a 'deficit' view of public knowledge, where the public are "...seen as empty vessels that need to be filled with the appropriate information regarding hazard exposure and the 'appropriate' adaptive behaviour to undertake" (Brown and Damery, 2002: 422-3) is now viewed as undesirable (Irwin et al., 1999). Such 'traditional' views argue that the public rarely have access to statistical information about risks, and subsequent risk perceptions are flawed due to the use of heuristics (Slovic et al., 1981), in addition to the limitations of personal experience (Kates, 1962). Constructivist views would suggest that “...both lay and expert risk perceptions ...may incorporate legitimate social judgements” (Jasanoff, 1998: 94). This thesis has taken a constructivist position (Section 3.2), and strongly argues for the need to study risk perceptions of the flash flood hazard within upland communities. These perceptions and viewpoints firstly influence the attitudes of residents and their responses to flash flooding; secondly, they have important implications for the implementation of institutional responses to flash flooding; and thirdly, they may differ from institutional views, as they are formed within a different (localised) context. Indeed, the Environment Agency’s responses to upland flash flooding could encounter difficulties as a result of local viewpoints, attitudes, and divergent opinions between local residents and authorities (Table 7.1).

During this project, differences in opinions have been found to exist between local residents (affected by flooding) and representatives from the Environment Agency, in particular, related to poor river maintenance and its influence upon local flood risk. Furthermore, negative viewpoints were expressed by local residents and the Environment Agency about each other, and the validity of each group's knowledge. Negative viewpoints of the Environment Agency from local residents have also been found in Pickering by the Ryedale Flood Research Group, where residents were frustrated with a perceived "...hierarchy of knowledge" and perceived that they "...were being 'made fun of' behind their backs" (Lane et al., 2011: 23). There was also a view that public meetings were used to reduce debate (Lane et al., 2011). In upper Ryedale, frustrations with the Environment Agency were also expressed, including views that the Agency did not appreciate local knowledge, and was remote and unaware of local situations. This questioning of flood management policies by some of the affected public following flooding has been noted elsewhere (Whatmore, 2009). The viewpoints expressed by local residents within this study are also similar to those revealed by Wynne (1996), whose research with hill farmers in Cumbria found that 'experts' were perceived to be "...ignorant but arrogant" (Wynne, 1996: 36) and did not value local knowledge and expertise. McKechnie's research on the Isle of Man into public views of radiation also described the construction and identification of expertise by members of the public, finding that "The possession of scientific knowledge did not appear to carry much weight in the evaluation of expertise" (McKechnie, 1996: 133) but instead "The authority to speak about any issue was allocated on the basis of a number of factors related to established local status and personal experience" and "...general knowledge, intelligence, and presentational skills were balanced with participation in local issues and specific local knowledges" (McKechnie, 1996: 131). The differences between the views of the Environment Agency and local residents found within this study can be placed in the context of the Environment Agency's commitment to working with local communities. As an example, the third of five tenets of the Agency's corporate strategy "Creating a better place 2010-2015" (Environment Agency, 2009*b*) was to "...work with people and communities to create better places" (page 4), an element of which is to "...engage with local communities to create a shared understanding of environmental issues" (page 19). Raising awareness of flood risks is a recommendation of recent strategies and reviews (DEFRA, 2005; 2011*b*; Pitt, 2008) and public and stakeholder engagement and involvement in flood risk management has advantages (White et al., 2010). After flood events, local residents frequently want to become more involved in making decisions (Whittle et al., 2010).

During this research, several residents of upper Ryedale have been shown to possess useful knowledge pertaining to local flooding. Some residents who had lived in the area all or most of their lives possessed detailed knowledge of past floods in the locality. In particular, floods in the early to mid-20th century, which occurred prior to official river monitoring by the Environment Agency, were recalled clearly by older residents, who included further details including the timing, nature, extent and cause of the flood events. A range of strong opinions on the factors influencing local flood risks, including the influences of land use and climate changes, were recorded in many interviews and questionnaires. Flash flood events are an example of a hazard which requires adaptation based upon risk perceptions and viewpoints of those at risk (Scolobig et al., 2009). With regard to natural hazards which occur and develop quickly, such as flash floods, the knowledge and awareness of local residents at risk is particularly important, given the limitations of traditional flood warning systems for the nature of the flash flood hazard (Associated Programme on Flood Management, 2007). In smaller catchments, individuals and communities typically lead the response, rather than institutions (Creutin et al., 2009).

Therefore, this project has provided a key insight into the nature of responses to upland flash flooding by residents of rural settlements, including factors influencing flash flood perceptions and responses to flash flooding (including the uptake of damage-reducing property-level modifications). This thesis has increased knowledge of how local perceptions of flash flood risks are generated, including the role of knowledge of past floods, their character, frequency and temporal distribution, in affecting perceived flood risk. Additionally, the finding that experience of flash flooding may not lead to increased perception of the flash flood threat is highly relevant to attempts by organisations to raise awareness of the hazard, or encourage responses, in line with national policies.

As well as improvements to the understanding of responses to flash flooding, the findings of this thesis are also relevant to research taking place towards other types of flooding, and other debates around flooding. In particular, surface water flooding is a highly salient issue. Following the 2007 floods in England and Wales (Marsh and Hannaford, 2007), reviews identified the poor management of surface water flooding (Environment, Food and Rural Affairs Committee, 2008; Pitt, 2008). The causative mechanism of the serious and widespread surface water flooding in Hull in 2007 was intense rainfall in summer (Coulthard et al., 2007), the same type of rainfall event which is responsible for many upland flash flood events (Section 1.2). In addition, surface water flooding occurs very quickly (Coulthard et al., 2007) and there is no national warning system for it (Coulthard et al., 2007; Coulthard and Frostick, 2010), further characteristics shared with upland flash floods (e.g. Collier, 2007; Cave et al., 2009 respectively). Several aspects and findings from this thesis are relevant to research into surface water flooding. The analysis of long rainfall time series, and the identification of changes to heavy and extreme summer rainfalls are particularly important in analyses of the physical risk of pluvial flooding: the greater intensity of summer rainfall resulting from climate change is the physical driver of many non-traditional flood types (Hankin et al., 2008). Participatory research with local residents directly affected by flooding, and assessing the nature of responses to flooding, and factors influencing them, also has significant benefits to the study of other floods. For instance, research into residents' recoveries from the 2007 surface water flooding in Hull by Whittle et al. (2010) found that council tenants, those privately renting and older residents were particularly vulnerable following the floods. In this study, those who rented their properties were identified as less likely to carry out household-level responses to flooding, and demographic factors (including age, and the number of people living at home) were associated with knowledge of services provided by the Environment Agency. Similarly, behavioural responses to flash floods (including greater awareness of river levels and concern during heavy rainfall) identified within this study were also found in Hull (Whittle et al. 2010). Additionally, research into the nature of community (as well as individual) responses to flood events, are important insights which can be taken from this project and contribute to overall knowledge about floods. The strong and resilient immediate response to the flash flood event by remote rural communities in upper Ryedale was also witnessed in Hull, as "...strong networks of support existed – or developed quickly – in the affected communities to help people cope with the unfolding disaster" (Whittle et al., 2010: 97).

Clearly, both upland flash floods and surface water floods are floods which are different from 'traditional' lowland flooding (river and coastal flooding), which is the type of flooding that the country, and institutions within it, is most prepared for (Environment, Food and Rural Affairs Committee, 2008). The shift to an increasing, yet highly uncertain future flood risk (Wheater, 2006) may be shown by an increase in both upland flash flooding and urban surface water flooding. Therefore, research into upland flash floods is clearly relevant to improving the understanding of a 'flood rich' period (e.g. Lane, 2008) and the ways in which residents respond to unpredictable, rainfall-driven flood events. Research into institutional responses to flash flooding, including the difficulties which the Environment Agency face in response to flash floods, and the identification of difficulties in the implementation of national policies at the local level (Table 7.1) are also extremely important, particularly as the Environment Agency is taking on an expanded ‘strategic overview’ role for all types of flooding in England, following the passage of the Flood and Water Management Act (2010) (DEFRA, 2011*b*).

The findings of this thesis also contribute to the understanding of local views of certain elements of the Government’s flood risk management policies. Natural flood management approaches are a part of government strategies (DEFRA, 2005) and recent legislation (Flood and Water Management Act, 2010; Section 2.4). Within upper Ryedale, an analysis of questionnaire and interview responses found that the maintenance of rivers, streams and drains was widely perceived to be an important factor influencing local flood risks. Over a quarter of questionnaire respondents (who provided an open response to the question) from Helmsley believed that the maintenance of rivers and streams was a factor affecting flood risks in upper Ryedale, considerably greater than the proportion of respondents viewing climate change as a factor influencing flood risks (12%) (Section 5.5, Table 5.15). However, perceptions of rainfall change within the population of upper Ryedale clearly demonstrate an awareness of a change to increased heavy rainfall and wetter summers, locally (Section 4.4). A very large flash flood event has taken place, as a result of extreme summer rainfall; however, the maintenance of rivers was more frequently, and more strongly, put forward as a factor influencing local flood risks than climate change. This may be related to the importance of an individual’s own observations in assessing flood causes (Whitmarsh, 2008). Responses in questionnaires and interviews gave opinions that river channels were poorly maintained, leading to a buildup of debris or vegetation. Several such responses emphasised the changing management of rivers (and drains), usually related to a reduction in maintenance procedures and practices. The following questionnaire comment, collected during the course of this project, clearly defines this issue:

As late as the 1980s there were men who worked on the Rye clearing debris, overhanging foliage, weeds etc. although the river used to break into lower lying fields, it was nothing unusual. Since the environment agency took control of such waterways, all maintainance seems to have come to a halt. As a result, there is a build up of rubbish, debris from the 2005 floods, weeds etc., and as a result the river rises very, very quickly with just "normal rainfall". I believe that a program of clearing work, as in the past, would allow a free flow of water, and stop this rapid rise in wet conditions.

Some interviewed residents provided opinions that wildlife and scientific interests were prioritised, reducing the maintenance of rivers:

Female: You see farmers around here can't clean the rivers out now. They used to be able to... if a tree fell they can't touch them.

Why is that... do you think that that might contribute to flooding, if there's debris and things going into the river...

Male: Yes, I mean if there's fallen trees it does that, like. Round here we have these dead trees and SSI areas... scientific.... special scientific interest places. Well if anything is blown down they really can't touch it.

The above viewpoints are clearly borne out of reliable personal knowledge, experience and observations. They are also linked to the findings of research: the aggradation of upland rivers has been linked to increased flood risks (Lane et al., 2007; Raven et al., 2009) and modelling within the Pickering catchment found that “...vegetation growth in rivers and on riverbanks can be a contributory factor in accentuating local flood risk” (Ryedale Flood Research Group, 2008*a*: 35). Reduced river maintenance can be conceptualised in a similar way to land use change: reduced maintenance and increased sediment aggradation on a localised stretch of river may influence flooding, just as land use changes are most likely to influence hydrology at smaller scales (Blöschl et al., 2007). Arguments about inadequate river maintenance have also been found in a number of other studies, reports and press across the U.K. (Environment Agency, 2007*b*; Werritty et al., 2007; Environment, Food and Rural Affairs Committee, 2008; Bunyan and Britten, 2009; Cave et al., 2009). The Environment Agency acknowledge that dredging has been reduced in rural areas since the 1980s (Environment Agency, 2007*b*). While the causes of river maintenance (or the lack of it) will vary in different locations, this study has highlighted local concerns of the impact that changes to natural flood management approaches may have upon rural flood risks. Such approaches may benefit large lowland settlements, but will raise flood risk in rural, lowly populated locations (Ryedale Flood Research Group, 2008*a*).

It is possible to make a further distinction between upland (rural) and lowland (urban) flood management, and the considerable disadvantages faced by upland areas despite their greater susceptibility to flash floods. Upland rivers tend to respond faster to rainfall than lowland ones (Knapp, 1979), there are clear differences between upland flash flooding and lowland river floods (Bronstert et al., 2002; Bronstert, 2003), and flash floods present a high threat to human life (e.g. Gruntfest and Handmer, 2001). However, the benefit:cost nature of flood risk management means that rural areas are likely to receive much lower investment than urban areas (Johnson et al., 2007), as are areas which experience "...high-impact low-frequency events" (Johnson et al., 2007: 383). It has been recognised that flood defence spending allocations greatly benefit urban areas over rural ones (Environment, Food and Rural Affairs Committee, 2008). Additionally, one of the Environment Agency spokesmen confirmed in interview that there was little that the organisation could do where flood defences and warning systems did not exist. Rural areas rely upon road and bridge networks for access after floods (Vinet, 2008) which when affected by flooding can hinder emergency response (Versini et al., 2010): a characteristic experienced during the upper Ryedale flash flood event. So, in addition to the greater physical risk of dangerous flash floods in the uplands, reductions in river maintenance within rural areas presents an additional factor to potentially increase the vulnerability of upland areas to flash flooding. Therefore, this thesis supports the recommendations made by the Ryedale Flood Research Group, that a reduction in maintenance "...should be regarded as an active intervention in the river system" and "...the concerns of those who could be affected by decisions to withdraw river maintenance are taken seriously, and that those who are concerned are fully and actively involved in the assessment processes" (Ryedale Flood Research Group, 2008*a*: 9).

7.4 Recommended responses to upland flash floods

So, following this research, how can upland communities best respond to flash flooding? An important positive finding arising from this study is evidence that rural communities, and those living there, are 'tough' and 'resilient', and can react to events without outside help. There is evidence of changes to behaviour and personal judgement in response to flash floods (including increased awareness of river levels and weather forecasts, evidence of unofficial warning systems (as described in Parker and Handmer, 1998), and residents' individual actions being triggered when the river reaches a mentally-defined 'worry level'). Some residents, including those with families or who have children living at home, are more likely to be aware of services provided by the Environment Agency. Initial responses to the flash flood were also dominated by the actions of residents, in the absence of immediate help from authorities, with many testimonies of the community spirit in the immediate aftermath of the flood event. The view was expressed by the Environment Agency during this project that more isolated, rural populations have an inherent resilience, which is of a significant benefit to hazard responses. While physical responses to flooding (in the form of modifications to properties) were limited, there was evidence of increased property-level resilience among many interviewees (most commonly, the placing of valuable items at a higher level) as well as changes to human behaviour (greater observation of river levels, weather forecasts and the perception of ‘panic levels’). Such measures constitute the most likely and useful responses to flash flood events: given the great danger posed by flash floods to human life (e.g. Gruntfest and Handmer, 2001), in the response to such events "...major emphasis turns toward saving lives rather than reducing property damage" (Gruntfest and Huber, 1991: 28). Therefore, the effective evacuation of residents out of properties to safety in the event of flash flooding should constitute a priority rather than expecting residents to adapt their properties to exceptional floodwaters, in areas where such events are rare. The encouragement of an increased uptake of major physical modifications to houses may be difficult, as risk perceptions may only lead to measures to increase preparedness that are relatively straightforward to carry out (Kirschenbaum, 2005), and a “...a complex mix of barriers” inhibits residents from increasing household resistance and resilience to flooding (Thurston et al., 2008: 14). The use of resistance and resilience measures at the property level in rural communities is recommended at the national strategy level (DEFRA, 2005) and recommendation 12 of the Pitt Review suggested that “All local authorities should extend eligibility for home improvement grants and loans to include flood resistance and resilience products for properties in high flood-risk areas” (Pitt, 2008: 79). However, the emphasis on ‘high flood-risk areas’ in this recommendation suggests its application to those areas which have experienced regular flooding.

A quote provided by one interviewee during fieldwork for this thesis described the tendency for what was described as "...folklore" to be disregarded by local authorities, and similarly the authorities not listening to the "...sages of the community". Local knowledge is extremely valuable: a study within Italian mountain communities prone to flash flooding found that local environmental knowledge, important for recognising danger and responding to it, had been lost (De Marchi et al., 2007; Steinführer et al., 2009). In this study, older residents, many of whom had lived most or all of their life in the area, possessed extremely useful knowledge of past flood events, including floods which occurred in the early 20th century. Other residents recalled minor, recent river flooding and documented major floods that had occurred in the past. There was also a perception expressed in interviews that flood risks were high in the summer. In this thesis, personal knowledge of past flooding has been shown to be linked closely to the perception of flash flood risks. Questionnaire analysis shows that residents who perceived that local river and surface water flooding was getting worse were more likely to recall more recent floods than those who disagreed that local flooding was getting worse. Using questionnaire and interview methods, this research has shown that a detailed, collective knowledge of past flood events can be compiled, including information on the date, extent, nature and cause of past flood events. As an example, a timeline showing recalled floods by surveyed residents (in interviews and questionnaires), compared with flood occurrences derived from discharge data and rainfall records ('possible overbank floods'), has been constructed (Figure 5.19). This information is more comprehensive than that which exists in discharge records (which are short in duration) and in written accounts. Therefore, a wider distribution of such information amongst local residents could increase their awareness of local flooding, as these residents would have access to a collective knowledge, rather than their own individual knowledge and experience, and its associated limitations for flood risk perception (e.g. Kates, 1962). Improved knowledge of recent floods (and very high river flows) may be particularly beneficial as the recollection of recent floods has been found to be associated with flood perception. Research at the University of Gloucestershire, using participatory research with members of the community, has involved the construction of past flood histories. An introduction to this approach points out that informal knowledge about flooding is often lost or reduced following the retirement of older people and a mobile floodplain population (McEwen, 2007). The benefits of a flood histories approach include greater awareness of flood risk and the encouragement of action and resilience:

> "This approach can then be used as a vehicle to support an exploration of what local flood risk means in a climate change context. Once flood awareness is broadly matched to the 'evidence' of flood risk, community members can then be encouraged to act in an informed way to mitigate against residual flood risk and the associated direct and indirect personal costs. This informed action is imperative for sustainable community development and increasing community resilience."
>
> McEwen, 2007: 4

Examples of flood histories projects were given in the McEwen (2007) best practice report appendix, including three examples from the U.K., one led by the University of Gloucestershire (in the Lower Severn area) and two led by the Environment Agency. The use of oral history accounts was an important method of research into past flooding on the Lower Severn Community Flood Network project (Insight - University of Gloucestershire, 2010).

This thesis has clearly found that local knowledge can be an extremely useful source of information on a number of subjects related to flooding. The benefits of participatory research to study local perceptions and viewpoints are clear, as "Catchments are... unknowable in objective terms" (Ison et al., 2007: 499). In this suggestion for increased participation, there is a clear parallel with the findings of the Ryedale Flood

Research Group, whose work in nearby Pickering has shown the advantages of integrating local people, and their knowledge, in scientific modelling. This research involved a “knowledge-theoretic” approach (Odoni and Lane, 2010: e.g. 151), where, instead of using modelling processes which are solely based upon theoretical and data-based knowledge, this approach...

> “...involves opening up the definition of what is admissable knowledge to include the collective knowledge, or competence, of those for whom the hydrology is both of material importance and, following Collins and Evans (2002), who have some kind of 'contributory expertise'. This might be the expertise that a hydrological modeller might bring from their modelling experience in other places and at other times; or it might be the expertise that someone who has lived next to the river has gained from watching the river over a period of time".
>
> Odoni and Lane 2010: 165

Crucially, the work of the Ryedale Flood Research Group in Pickering “...revealed a widespread distribution of a deep qualitative understanding of flood hydrology” (Lane et al., 2011: 32) among residents. The detailed, experiential knowledge possessed by residents and used during the modeling work led to “...a shift from (local residents) taking knowledge as a given, to being able to see the model predictions as just one set of knowledge, against which they were entitled to compare and use their own knowledge” (Lane et al., 2011: 31). Therefore, the “...sense of knowledge” changed (Lane et al., 2011: 31). This represents the ‘co-production of knowledge’ model proposed by Callon (1999, cited in Pouliot, 2009; Lane et al., 2011) and (similarly) ‘knowledge co-generation’ as described by Klein et al. (2011). This is distinct from usual participation and stakeholder inclusion (Landström et al., 2011).

Identifying those who possess detailed knowledge of local floods may be an important step in initiating participatory, and/or discussion processes. From this project, older residents who have lived in an area for a large portion of their lives, and residents living near a river who express an interest in, and knowledge of, issues related to local flooding, may form examples of 'uncertified' or "...experience-based experts" experts (Lane et al., 2011; Collins and Evans, 2002: 251, respectively). Similarly, Wynne (1996) described expertise within Cumbrian hill farmers as "...not codified anywhere: it was passed down orally and by apprenticeship from one generation to the next, as a craft tradition, reinforced in the culture of the area" (Wynne, 1996: 36). During research by McKechnie (1996) on the Isle of Man, members of the public recommended other people, who they perceived as particularly knowledgeable, for the researcher to talk to, providing "...access to a shared, local mapping of expertise" (McKechnie, 1996: 131). Particularly important residents in participatory schemes are 'gatekeepers': "People, who through their own interest, activities and even work had (have) access to, and engaged with, others in the community" (Petts, 2007: 304). As an example, within this study, a local businessman, also a local councillor, whose premises had been affected by flash flooding, was mentioned in separate interviews and was regarded as 'good to speak to' for the research project.

Participatory research into rural issues, including the engagement with stakeholder knowledges, has been carried out as part of other research projects, including the Rural Economy and Land Use project (Dougill et al., 2006). The potential benefits of the use of oral history methods to study past floods have also been noted (McEwen, 1987). The detailed knowledge of local flooding (particularly from older residents) revealed during this thesis could be put to a more productive and beneficial use, through its wider dissemination and discussion. Expanding the community knowledge of flooding this way has a parallel with the use of competency groups in Pickering, which "...aim to intervene in the generation of knowledge in situations when existing knowledge does not suffice" (Landström et al., 2011: 1631). Furthermore, the controversies linked to flooding arise due to differences between scientific risk assessments, and knowledge gained through local experience (Whatmore, 2009). Within this thesis, the dissatisfaction expressed by local residents with the Environment Agency, the viewing of the Agency as a remote organisation, and arguments about the role of river maintenance in causing local flood risk, can be described as controversial issues.

A recommended use of participatory techniques is a reflection of the constructivist and pluralist view of risk perceptions, and its implications for policy (as described by Jasanoff, 1998). Broad environmental issues are always understood within local contexts (Bickerstaff and Walker, 2001). Experience, individual judgements and memories (among other things) are used to deal with new issues within a local context (Irwin et al., 1999). Irwin’s (2001) further analysis of environmental pollution in Jarrow, England stated that local viewpoints of environmental problems are "...dynamically and discursively formed within a given context" using discourses such as "...the importance of local memory, the use of evidence and expertise, and the expression of moral judgements" (Irwin, 2001: 105). This "...knowledge gained from experience" (McKechnie, 1996: 135) has been found within the research for this thesis, in the uncovering of detailed, highly relevant knowledge about the role of poor maintenance of rivers affecting local flood risks, the recollection of information about past flood events (unrecorded by more modern discharge records), and knowledge of changes to patterns of rainfall. Local residents within upper Ryedale may possess 'contributory' and 'interactional' forms of expertise (as defined by Collins and Evans, 2002; Carolan, 2004). Using proposed definitions of these terms, certainly local residents' understandings of issues related to flooding provide them with "Enough expertise to contribute to the knowledge base of the topic in question" and such residents may also have "...enough expertise to allow for interesting interactions between contributory experts" (Carolan, 2004: 423, based upon definitions provided by Collins and Evans, 2002:

254). The recommendation which this thesis makes is for participatory work to benefit local communities, by increasing the collective local knowledge.

Increasing awareness of flooding is an important aim of recent national policies (e.g. DEFRA, 2005; Section 1.3), and maintaining awareness during periods where few floods take place is difficult, but using past flood experience is one way of raising and maintaining awareness (Kreibich and Thieken, 2009). Further literature suggests other methods of increasing awareness, include the installation of flood marks in public places and information gatherings (Petrow et al., 2006): historical epigraphic records (e.g. flood marks on bridges) constitute an important historical record of flooding (Macdonald, 2007) and can increase local knowledge of floods, acting as a link to past flood experience and as a reminder of flood capability (Macdonald, 2011). Furthermore, a survey of public views on the Environment Agency's flood maps found that three-quarters of respondents wanted information on past floods to be included with the map (Priest et al., 2008). The ideal role for the Environment Agency, or other authorities, may represent what White and colleagues describe as "...moving away from a deliberative consultative approach towards a more active facilitative process" in public engagement (White et al., 2010: 345). As motivation to respond to flooding (flood insurance) has been observed to decrease with time following a flood (Baumann and Sims, 1978) and awareness of flood risks also reduces over time (Raaijmakers et al., 2008), raising awareness in communities must be a long-term process, as opposed to a more typical burst of activity following a flood event, but declining interest after that (Associated Programme on Flood Management, 2007). Therefore, there is a need for "...a continuous effort" in raising awareness of flood risks (Steinführer et al., 2009: 43).

Based upon the wide range of photographs, newspaper cuttings and other media and information presented to the researcher of this thesis during interviews, there may be a large amount of material and information available in upland villages and towns about flooding available for discussion. The use of such material and objects which reminded residents of their past flood experience was used to start discussion in the participatory research of the Ryedale Flood Research Group (2008*a*): these objects played a role in exploring the 'mess' of the local flooding issue (Donaldson et al., 2010). Longer-term participatory methods of flood research also provide examples of potential methodologies: research in Hull used personal diaries, written over an 18 month period to document the process of flood recovery (Whittle et al., 2010); similarly, research into the health impacts of flooding used three focus groups over a four and a half year period (Tapsell and Tunstall, 2008). The Pitt Review notes that “Flood forecasting and warning services are not just about event-specific warnings, but also about year-round awareness raising and information” (Pitt, 2008: 318) and the Review also notes the use of diaries of past flood events to increase flood knowledge and awareness in a community group (Pitt, 2008), a participatory technique described above.

Therefore, there are methods of participation in existence which could be used to “...actually engage communities and encourage ownership of flood knowledge” (McEwen, 2007: 4). In particular, locally specific knowledge of long-standing residents who have extensive experience of living in an area must be recorded. The limitations of such an approach may be that tourists and transient visitors, who often visit locations at risk of flash flooding (Cave et al., 2009) may be excluded: the vulnerability of caravan parks to flooding is particularly high (McEwen et al., 2002) and the fortunate escape of attendees at a motorcycle rally based at a campsite (Wass et al., 2008) was noted in this thesis.

Recommendations for raising awareness and enforcing statutory requirements in these areas have been made (Cave et al., 2009).

Similar to the knowledge of past floods described above, other local knowledge has been found in this project which, if shared and distributed among a wider audience, may have the potential to increase flash flood awareness. A number of residents expressed viewpoints about the local climate, with many identifying a recent increased intensity of rainfall and a trend to wetter summers which corresponded well to actual rainfall patterns; providing evidence that several residents have an interest and understanding of the local climate and environment. Increases in the frequency of heavy rainfall may be linked to an intensified hydrological cycle in a warmer climate (Frei et al., 1998), and increases in summer heavy rainfall are directly linked to increased flash flood risks, as flash floods and the intense rainfalls that cause them tend to occur in this season (Merz and Blöschl, 2003; Section 1.2). While U.K. rainfall analyses have emphasised increases in the frequency of winter heavy rainfall since the mid-20th century (e.g. Osborn and Hulme, 2002), rainfall analysis from this project suggests that heavy summer rainfall is typically more extreme than heavy rainfall in other seasons. Therefore, in order to raise awareness of flash flood risks the danger presented by extreme and intense summer rainfalls in upland areas needs to be emphasised.

However, despite knowledge of the local climate, views of greater extreme rainfall occurrence among residents were only occasionally related to increased flood risks locally, which were regularly perceived to be a result of reduced river maintenance. In addition to valid local observations of the local environment, this may be linked to known difficulties in the perception of climate change: it is difficult for individuals to appreciate and recognise large scale or global changes to climate as they are "...highly abstract, happening on a huge scale, and can't be experienced directly" (Kearney, 1994: 419). Residents are most likely to construct climate through personal experiences, rather than through statistical analyses (Hulme et al., 2009). In the same way that greater knowledge of local flood histories may increase awareness of flood risks, are there any sources of information, held by residents, available which reveal changes to the local climate?

During this research project, it was found that locally based rainfall data does exist in the form of private rainfall records, kept by some residents as a hobby. These rainfall records were closely comparable to 'official' rainfall records: this is an example of local knowledge reflecting that produced by wider institutions (Irwin et al., 1999). These privately held records clearly showed a recent increase in summer and annual rainfall totals, reflecting the rainfall records kept by the Met Office which are not publicly available. Furthermore, an analysis of questionnaire and interview responses showed a broad perception of recent increases in the 'wetness' of the 2000s period, and increases in summer rainfall and heavy rainfall: factors leading to an increase in flash flood risks, due to the typical timing of flash floods and causative rainfall (Merz and Blöschl, 2003). As there is evidence that changes to local climate are known, but not widely viewed as a contributing factor to local flood risks, it is possible that with collaborative efforts between residents, such local rainfall records could be made public and shared. The sharing of such data already occurs: websites exist with uploaded, real time weather information sourced from independent weather stations: for example, http://www.weatherstations.co.uk/aws_map.htm (Prodata Weather Systems, 2011) includes links to a number of stations within the U.K. and Ireland, including a number of weather stations located in rural and/or upland areas producing freely available, real time weather data. An example of publicly available weather records are those from a weather station in the Lake District based in the Keswick area, which provides (at the time of research) daily weather reports and an archive of records running back to August 2000 (Colam, 2007). If knowledge of such datasets was more widespread, and discussion of local climate data was facilitated, perceptions of changes to climate may be reinforced and local awareness of increases to local flood risks increased.

An important question, therefore, is ‘how can such discussion be encouraged, and initiated?’ The competency groups at Pickering were driven by “...visceral experiences of the recent flood event and frustrated dealings with flood-risk ‘experts’” (Whatmore and Landström, 2011: 593). Anger from the public often follows flood events (Samuels et al., 2006) and those that have experienced flooding have been found to be strong and vociferous during engagement with authorities, a form of “Victim pressure” (Harries and Penning-Rowsell, 2011, quoting part of the article title). McEwen (2007) summarises that many “Community engagement with local flood histories and flood risk” projects (McEwen, 2007: 12) are started as a result of “...an enthusiastic champion who is keen to develop and promote the initiative. Most are characterised by the mobilisation of volunteer labour, and with very varied degrees of formal funding” (McEwen, 2007: 12). McEwen’s experiences of community engagement led to an observation that large events, such as floods, can provide an opportunity for such engagement (Klein et al., 2011). In this study, the first interviews with residents took place around three years after the flash flood event occurred, therefore the salience of the hazard was reduced. Attempting to provoke discussion of flooding somewhat closer to the occurrence of flood events may be more effective. For upland flash floods, this latter point may be particularly important, as this thesis has found that such floods may not, by themselves, lead to increases in the perception of the local flood hazard. The Ryedale Flood Research Group project in Pickering was advertised locally, and members of the group were asked to take with them objects associated with their flood experiences, which led to discussions (Ryedale Flood

Research Group, 2008*a*). However, within this research project into the more specific upland flash flood hazard, flood risks within the upland community studied were widely perceived to be lower than those in other nearby settlements, and relatively low numbers of surveyed residents agreed that local fluvial floods were getting worse.

However, this thesis has discovered issues which are controversial, and/or key, common points of discussion among residents of an upland catchment, which could be used as useful starting points for discussion and could act as ‘entry points’ to debate. Whatmore (2009) noted that those affected by flooding often "...contest the expert knowledge claims and practices associated with the science and management of flood risk" (Whatmore, 2009: 594). A strong feeling was held by several residents that poor maintenance of watercourses was a key factor affecting flood risks. Interviewed residents from upper Ryedale argued that the management and maintenance of rivers was worse than it used to be, and the opinion that wildlife and scientific interests were prioritised, reducing the maintenance of rivers, were also revealed. This thesis has also found evidence of local residents’ frustration with the Environment Agency, which has also been found within the Ryedale Flood Research Group study in Pickering (Lane et al., 2011; Whatmore and Landström, 2011). In upper Ryedale, there was evidence of dissatisfaction with the services provided by the Environment Agency, an opinion that local knowledge was ignored by local authorities, and also a view that the Environment Agency did not understand the nature of the local area.

Therefore, the use of innovative participatory methodologies, based upon the longer-term involvement of local residents and stakeholders affected by flash flooding, aimed at increasing awareness of local flooding, flood knowledge and changes to climate, has the potential to prevent residents of upland communities at risk of flash flooding being

"...prisoners of their experience" (Kates, 1962: 140), and provide a way of adapting attitudes which otherwise restrict raising awareness and responses to flooding (Borrows, 2006). These methods would support the aims of national flood management policies and strategies, as well as broader shifts to flood risk management approaches (described in Section 1.3).

The use of local knowledge, observations and data about the physical environment in order to support personal perceptions also shows a potential strength and advantage of the interdisciplinary method. Any attempt to manage upland hazards such as flash flooding requires a fundamental knowledge of the inability of national institutions to monitor, react to, and have responsibility for such hazards. Additionally, an acknowledgement should be made that the impacts of climate change upon upland areas are likely to vary, and be perceived in different ways by flood risk managers and local residents, based upon the different contexts in which information is received. It is difficult to perceive hazards resulting from climate change at the local level. Finally, if local resilience and self-reliant attitudes are in evidence, attempts to increase flash flood awareness and responses should complement them.

Chapter 8

Conclusion

This conclusion outlines the findings of this thesis, based upon the thesis objectives (Section 1.4) and the thesis aim. Additionally, this conclusion reflects on the research approach taken and also makes suggestions for future research into responses to flash floods. This thesis used an interdisciplinary methodology in order to gain a greater understanding of the factors influencing local responses to upland flash flooding, as well as the ways in which institutional responses and policies to deal with flash flooding are implemented. The aim of this thesis was to analyse the effectiveness of local- and national-scale responses to upland flash flooding, based upon assessments of the physical flash flood hazard, local adaptations and perceptions, and the flood risk management policy context. The first section of this conclusion summarises the thesis findings, in relation to the four thesis objectives described in the introduction.

8.1 Summary of thesis findings

The first objective of the thesis was *to assess the extent to which past flooding in an upland area can be reconstructed using hydrological and proxy records*. The short-term nature of river flow records means that other sources of data (documentary sources and residents' memories) must be used to research past flooding within an upland catchment. Patterns of high flows within upper Ryedale suggest that the 2005 flash flood was highly unusual, and that high flow events in summer are more extreme than winter high flows, and summer events are faster rising than events in other seasons. As heavy rainfall in summer is also more extreme than that in other seasons, a period of wet summers increases flash flood risks. An additional method of using the relationship between high river discharges and rainfall, and the subsequent use of rainfall records to identify ‘possible overbank floods’, has been used to attempt to overcome the limitations of a short upland river discharge record. Local residents’ knowledge of past flood events is associated with perceptions of flood risk, a characteristic found during both questionnaires and interviews. Memories and recollections of local residents about flooding are more detailed than short discharge records.

The second thesis objective was *to evaluate the 2005 flash flood in the context of the long-term hydrometeorological record*. Clearly, the 2005 flash flood in upper Ryedale was an extremely rare hydrological event, resulting from an exceptional response of an upland catchment area to intense and localised rainfall (Wass et al., 2008). A compiled long-term daily rainfall series (1916-2009) shows an increase in the magnitude and frequency of heavy rainfall events from the 1960s onwards, although the full record suggests alternating periods of high and low frequencies of heavy rainfall. Heavy summer rainfall events tend to be more extreme than heavy rainfall events in other seasons, and thus contribute more to flash flood risks: such rainfalls have sharply increased from the late 1990s to the 2000s. Intense upland rainfalls occur more frequently than flash floods do: therefore, increases in flash flood risks (resulting from climate change) are difficult to perceive within a local context. Other sources of rainfall data assessed within this thesis include residents’ perceptions and private rainfall records.

The third objective of the thesis was *to analyse public responses to the 2005 flood and the level of flash flood knowledge and perception amongst the residents of upper Ryedale, and the factors which influence them*. Most responses to flash flooding by directly affected residents were behavioural in nature, in addition to straightforward measures to increase household resilience. Substantial physical responses were far more infrequent, and were related to the repetition of flood experience and concern. Flood perceptions were related to the knowledge and experience of past flood events (frequency, timing, flood type, knowledge of flooding in other catchments). An upland flash flood, by itself, is not enough to increase perceived flood risk. Responses to flash flooding were associated with the level of flood hazard perception, as well as to demographic, socio-economic and attitudinal factors. Residents are most likely to believe that the maintenance of river channels influences local flood risks.

The fourth, final objective of the thesis was *to assess the implementation of changes to flood policy, and institutional responses to flash flooding*. Flash floods pose several difficulties for organisations such as the Environment Agency, in particular, due to issues related to flood monitoring and warning systems. A number of policies and strategies have recognised the need to manage non-traditional flooding (pluvial and surface water flooding) due to the experience of such floods from 2000 onwards. These include awareness-raising, and encouraging local responses to flooding. Modifications to upland land use have taken place in catchments near upper Ryedale which have experienced frequent and (on average) quicker rising river flows, and where local awareness of flooding is high. Attempts to encourage local residents to take substantial actions in response to flooding are unlikely to be successful in the case of upland flash floods. The nature of flash flood perceptions, attitudes and viewpoints uncovered during this research at the local level may hinder the effective implementation of national policies and responses to flash flooding. Upland residents are unlikely to be aware of the Environment Agency’s warning and information services.

As perceptions of flash flood risks are strongly influenced by an individual’s knowledge of local flooding, it is possible that a wider dissemination of locally derived knowledge and information may increase local awareness of upland flood risks. Potential methods to achieve this include the collective compilation of local flood histories, and the sharing of locally collected rainfall data may also be used to support existing perceptions of increases in heavy summer rainfall. A strong advantage of innovative participatory research, including research into local flooding issues, is its ability to produce knowledge (Landström et al., 2011): the form of participation that this thesis recommends is not participatory research *per se*, but instead is a means of facilitating local discussion to increase upland community understanding of local flood risks and past floods, and changes to climate which may increase the risk of flash flooding.

8.2 Thesis contributions, and recommendations for future research

This thesis has improved the understanding of the responses to upland flash flooding at both the local (resident, household, community) and institutional (responses by the Environment Agency) scales. The thesis contributes towards an expressed need for qualitative research into perceptions of flash flooding (Cave et al., 2009) and a broader requirement for interdisciplinary research in flood risk management (Mostert and Junier, 2009). The findings of this thesis have emphasised the benefits of flash flood research which is interdisciplinary and participatory in nature, incorporating the study of local perceptions and viewpoints. In addition, this thesis has recognised the differences between responses to upland flash flooding in comparison to areas experiencing frequent flooding. This can be discussed in the context of classic natural hazards literature, and more recent research on preparedness. Similarly, the difficulties faced by institutions in managing upland flash floods have been described. Additionally, potential difficulties in the implementation of national-scale responses to flash flooding have been identified. Finally, the thesis has contributed towards a greater understanding of the physical hazard of upland flash floods, based upon analyses of rainfall trends and patterns (particularly in heavy summer rainfall) and also the nature of high flow events.

The flash flood hazard clearly requires ongoing research, based upon established areas of uncertainty in both physical science and social science domains (Montz and Gruntfest, 2002). Attempts to improve the understanding of physical processes involved in flash floods include the compilation of a Europe-wide database of flash flood events (Gaume et al., 2009) which may increase the understanding of relationships between rainfall events, hydrological processes, river basin characteristics and other factors. While improvements in warnings are extremely important, they are undeniably highly difficult (Alfieri et al., 2011) with improved precipitation forecasts required (Hapuarachchi et al., 2011). The Environment Agency and Met Office now have a joint forecasting centre (U.K. Meteorological Office and Environment Agency, 2009*b*); additionally, the use of a radar-based early warning system, created in collaboration with a parish council in a neighbouring upland catchment, was pointed out by the Environment Agency during this research. The use of such systems at a wider scale in a large number of upland areas at theoretical risk of flash floods is impractical. For the researcher, studying the physical risks of flash flooding is difficult, as there is a low volume of ‘raw’ physical data which can be collected on upland flash floods, as a result of the rare nature of flash floods (e.g. Gruntfest and Handmer, 2001), the fact that such events are difficult to monitor (Creutin and Borga, 2003) and the nature of discharge records in upland areas, which are few and far between (Macklin and Rumsby, 2007). The methods used within this thesis have aimed to overcome this issue, and some recommendations can be made for future studies of upland flash floods. Firstly, short and discontinuous physical data series (daily rainfall) can be carefully extended using techniques of gap filling, using correlation and regression methods, and the formation of composite records. As the uplands are a source of flood events, long rainfall records from these areas are extremely valuable (Burt and Ferranti, 2012) and long-term monitoring provides a fuller context for more recent changes (Robson et al., 1998). Secondly, there is considerable scope to use qualitative and semi-quantitative data sources, collected using social science methodologies, to study characteristics of the physical environment (rainfall and river flows). Finally, a method of identifying possible past floods using daily rainfall series may offer potential benefits with further investigation and methodological refinement.

The difficulty in preparing effectively for flash floods is related to the observation that "...the flood events that require the greatest level of preparation and response are very rare" (Burn, 1999: 3452), however "...because they are rare, the motivation to invest time and resources into such activities is low" (Montz and Gruntfest, 2002: 16). A shift to a period of increased, but uncertain flood risks (Wheater, 2006) may be evidenced by the occurrence of upland flash floods, and may also be demonstrated by the occurrence of other rainfall-driven floods, such as urban surface water flooding (e.g. that in Hull in 2007, Coulthard et al., 2007). It is extremely debatable as to whether the country is prepared for this. The national flood warning system is not designed for flashy, sudden floods (Pitt, 2008; Twigger-Ross et al., 2009), river and coastal floods are the dominant focus of flood risk management in England (Environment, Food and Rural Affairs Committee, 2008) and the Environment Agency's difficulty in responding effectively to the flash flood hazard has been clearly identified within this thesis. At the same time, changes to flood policies place more responsibility on the public to manage their flood risks (White et al., 2010). Therefore, further research should take place into local-level responses to floods in areas where the risk of flooding is rare, but floods are likely to be highly dangerous when they do occur. An important institutional response to flash flooding is the identification of rapid response catchments by the Environment Agency (e.g. DEFRA, 2005; Cave et al., 2009); future research into the response to rare but dangerous floods will complement this approach. This thesis has increased the understanding of the vulnerability of upland communities to flash floods (Figure 7.2) and has identified key factors associated with responses to an upland flood event.

The focus of future research into flash flooding should concentrate upon responses to such events and the nature of hazard perception. The case study approach used in this thesis, conducting research into one particular flash flood event, has the advantage of depth over breadth. However, the use of comparative studies may prove particularly beneficial, particularly as a comparison of the upper Rye catchment (the focus of this study) and other nearby settlements in North Yorkshire has shown that the nature of flooding can vary considerably in a small area, particularly in terms of flood frequency. As a result, local flood perceptions and responses are very different between the two areas. An example of a much broader comparative study is the research of Steinführer et al. (2009) into risk constructions, vulnerability and resilience to flooding, which incorporated case studies from three European countries, with a selection of locations (including urban and rural locations) that had experienced different types of floods (including flash floods) and had different flood histories. That project concluded that an approach to social vulnerability should be (among other things) "Context-sensitive" (based upon differing risk cultures "...between and within regions") (Steinführer et al., 2009: 43). Comparative studies bring advantages for research findings generally, as comparisons of interdisciplinary studies can provide "...important insights into diverse complex characteristics that cannot be observed in a single study" (Liu et al., 2007: 1516). Within larger upland regions in the U.K., over longer timescales, flash floods occur relatively frequently (Carling, 1986; McEwen and Werritty, 1988). For example, the flash flood in upper Ryedale occurred approximately two years before, and 110 km away from, a flash flood in Alston, Cumbria which caused one death, damage to more than 20 homes and roads (Cumberland and Westmorland Herald, 2007). Therefore, there is considerable potential, given awareness of the occurrence of flash flood events, for somewhat ‘opportunistic’ comparative studies of community responses to, and perceptions of a) different upland flash flood events, and b) flash floods and different types of flood in nearby areas.

Finally, as a general statement, "Interdisciplinary research is difficult" (Mostert and Junier, 2009: 4977) as during the practice of interdisciplinary research, researchers "...need to be willing to learn new things and familiarize themselves with concepts and approaches that are often fundamentally different from the ones that they are used to" (Mostert and Junier, 2009: 4977). Those that practice natural and social science research use contrasting methods and research techniques (Strang, 2009). Good interdisciplinary researchers should be flexible, adaptable, and creative (adapted slightly from Bruce et al., 2004: 464) and researchers should use an exploratory, rather than reductive approach (Bruce et al., 2004). Within this thesis, a thorough exploration of information found within different datasets (e.g. assessing all possible relationships between questionnaire variables, carrying out several different forms of data analysis of rainfall data, and reading through transcripts of interviews) was required in order to assess possibilities for data integration. The upland flash flood hazard is far too complex to be approached from the viewpoint of a single discipline. It has been observed that "A good interdisciplinary researcher will... have a high tolerance for ambiguity" (Bruce et al., 2004: 465). This project has found that uncertainty over the way data will be integrated is normal, and should be accepted: as noted by Bryman, in the integration of quantitative and qualitative research, it is “...inevitable that some outcomes will be unanticipated” (Bryman, 1992: 68). The complexity of interdisciplinary research arises as the disciplinary boundaries, which define to a large extent the methods used and form of research (Bruce et al., 2004) are removed. During this research project, some elements of physical data analysis were undertaken based upon the findings of social science research: for instance, expressed perceptions and viewpoints about the spatial and temporal nature of flood events. The utilisation of local knowledge to aid the course and form of scientific research has been carried out by the Ryedale Flood Research Group, in what was described as a "...knowledge-theoretic" approach (Odoni and Lane, 2010: e.g. 151) where the observations and experience of local residents affected by flooding played a major role in the form of modelling (Lane et al., 2011). While such sustained participation has not constituted a method within this thesis, a key interdisciplinary component of this research methodology has been the identification of opportunities to compare and contrast views and perceptions with available physical data.

Appendix 1

Sample interview outlines

The following appendix contains three sample interview outlines as used during fieldwork for this piece of research. The first is an interview schedule/pro forma for the interviews with residents of upper Ryedale which took place within 2008 (A1.1). The second outline is for the interview with the two spokesmen from the Environment Agency which took place in 2010 (A1.2). One of these interviews took place at the Environment Agency's area office in York and other took place at Darlington train station. The final part of this appendix is a list of the main questions asked to a representative from Ryedale District Council, derived and paraphrased from the transcript of the interview (A1.3). The latter interview also took place within 2010 at the District Council offices in Malton. These outlines are slightly modified from the original documents to improve clarity. Additional notes referring to the content of the outlines are included in boxes.

A1.1 Interview schedule 1: interviews with residents of upper Ryedale

Flood interview questions

How old are you?

How long have you lived at your property for? Since when?

Before the flood/flooding trends

Before the flood in 2005, did you consider your property to be at risk of flooding? (If yes/no, why?)

Did you know that your house was located on a floodplain?

Before the flood, did you think that a major flood (as in 2005) could occur?

Before the 2005 flood, did you take any precautions to protect your house/property against flooding? (If you did/didn't, why did you take/not take them?)

Are you aware of any other floods which have occurred in this area, apart from 2005? Did you experience these floods yourself?

Over the time you have lived here, do you think that floods in Ryedale are occurring more frequently? Do you think that they are getting more serious?

Do you think that floods in the country as a whole are getting more frequent/severe?

Do you think that other major floods will occur where you live in the future?

2005 floods

Thinking back to the evening of the 19th July 2005…

Where were you when the flood hit?

Before the flood occurred, did you notice anything which led you to think that a flood was about to occur (e.g. weather, observations). Did you view these as warning signs?

How did you first find out that a flood was occurring (neighbours/warnings/TV or radio/your own observations)

Did you notice how heavy the rain was/how quickly the river rose?
Did you help out any other residents during the flood?

When the flood occurred, did you do anything to protect yourself and your property?

What sort of damage was caused to your property?

What sort of emotions did you feel during the flooding?

How long did it take to get your house/business back to the way it was before the flooding?

How long did the community take to get back to normal?

Did the flood have any effects on your health and well being?

Was there a response by the community to the floods? How effective was it?

Was there are a response by the local authorities to the floods? How effective was it?

Do you view the flood of 2005 as a one-off event, or part of a longer trend of increasing flooding? (Why would you say that?).

Adaptation to the floods and other views

"What have you done in response to the flood, and why you have done it"

Since the flood in 2005, have you done anything to protect your property from flooding? If so, what did you do? What was your intention?

If you have done nothing, why have you done nothing?

Have you changed your own behaviour to take into account flood risk (e.g. greater awareness of flood warnings, river levels, weather forecasts)? If so, why? If not, why?

Are you aware of any other ways in which you can protect your property from flooding?

What would it take before you decided to do more to protect your home?

Do you think that your actions will be effective in preventing future flood damages to your property in future?

What do you think are the best ways in which people who live in an area at risk of flooding can protect themselves against it?

Whose responsibility should it be to prevent flood damage in your home? Do you think that local authorities could do more?
Would you say that what you have done is a reaction to the flood in 2005, or an anticipation of future floods? (or both)

Do you think that if the flood event in 2005 happened tomorrow, the damage to your property would be the same?

Have your views on floods getting worse in the future (if that is the interviewee's viewpoint) influenced your decision to take action?

Are you aware of anything that other people in this area have done to protect against flood damages?

Views on flooding and adaptation

How has the 2005 flood changed your views about flooding and the risks it poses?

Are you concerned about the possibility of future flooding?

What would you say to the statement that “there is little we can do prevent flood damage as floods are natural processes”?

Do you think that flood damages are inevitable if people live in an area where flooding occurs?

Flash flooding and mitigation measures

How would you define the term ‘flash flood’?

Why do you think that no official warning was given for the flood on the 19th July 2005?

Why do you think that the river Rye rose very quickly? Apart from the rainfall, is there anything about this area that makes the river rise quickly after rainfall?

Do you think that people have increased the flood risk in Ryedale?

Are you aware of any of the following[1]:

- Floodline telephone warning service
- Environment Agency floodplain maps
- Environment Agency flood warnings and codes. Also, where would you see them?
- The Environment Agency’s recommended flood kit, and recommendations for actions during flooding
- Anything that the government is doing to protect against flooding?

[1] – Environment Agency services (Floodline, flood maps, flood warning symbols) are described within Section 3.8.2 of the thesis.

A1.2 Interview schedule 2: interviews with spokesmen from the Environment Agency

Interview aims

- Explanation of the ways in which national (and European) flood relief policies are implemented and modified at a local scale, and how useful these policies are for dealing with flash flood risks.
- Assessment of the response of stakeholders to flash flooding
- Stakeholder views on climate change, factors affecting local flooding, and knowledge of flash flood genesis and mechanisms of local flooding (and contrast with local knowledge).

Interview topics list

Introduction

- Own career - years in service, areas of responsibility, experience of flooding

- Knowledge and involvement with Ryedale flash flood in 2005

Environment Agency warning services - uptake in the upper Ryedale area and factors affecting uptake of services.

- Uptake and awareness of flood warning services and challenges in dealing with this area

- Understanding and receptiveness of local residents of flood warning systems and advice given to them by the Environment Agency

Local responses to flash flooding

- Responses to 2005 flash flooding - by local residents, and by local authorities and the Environment Agency. Views on the effectiveness of these responses.

- Factors influencing these responses e.g. what makes someone opt to take measures to protect their house.

- Local hazard perception, views on flooding, and risk response.

Local knowledge and flood information

- Views on the usefulness of local knowledge about changes in climate, flood risk, factors influencing flood risk

- The involvement of local people, and their knowledge, in the formulation of strategies to deal with flood risk in the local area.

- The use of locally-sourced data (e.g. rainfall, discharge records) in the assessment of local flood risk

Factors affecting flood risk in upper Ryedale

- Awareness/views of history of flooding in upper Ryedale - what floods have occurred in the area in the past

- Land use change in the catchment and human influence on flood risk

- Climate change and rainfall patterns - knowledge of changes in rainfall patterns in upper Ryedale, North York Moors. Trends in rainfall (seasonal rainfall, heavy rainfall) over the long-term (century scale) and last 10 years.

- Timing of floods (relative flood risks at different times of the year)

- Genesis of floods (mechanisms which cause flooding in upper Ryedale)

- Relative risks presented by different types of flooding - flash flood in Helmsley vs regular flooding in other areas e.g. Pickering, plus flood in 2000.

- Responses to 2005 flash flooding - by local residents, and by local authorities and the Environment Agency. Views on the effectiveness of these responses.

Policy

- With respect to upper Ryedale, views on the government policies most frequently used in relation to flood risk across both North Yorkshire and in upper Ryedale

- Derwent Catchment Flood Management Plan (2007)[1] - ways to manage flood risk and application to upper Ryedale

- Yearly maintenance program (p11)
- Flood warnings uptake figures (p13)
- Possible changes to present day land use (p16) - have any of these been considered?
- Management of flood risk in the catchment overall, its application to upper Ryedale and its effectiveness (schemes on p19-21)
- Flood risk mapping in Helmsley (specific policy to Helmsley area, p28)
- Maintenance of flood defences (specific policy to Helmsley area, p28)

- Views on the application of Making space for water[2] approach (living with/accepting floods) in upper Ryedale

- Views on development planning policy (PPS 25)[3] and its application to upper Ryedale

- Views on the recommendations of the Pitt Review (2008)[4] relevant to the Environment Agency and flood risk management (e.g. national overview role for all types of flood risk, greater focus on the management of surface water flooding, improvements to flood warning services)

- Issues between management strategies and policies of the North York Moors National Park Authority and Environment Agency / flood risk management in general.

Documents/references mentioned within above text:

[1] – Environment Agency, 2007*a*
[2] – DEFRA, 2005
[3] – Department for Communities and Local Government, 2006
[4] – Pitt, 2008

A1.3 Interview schedule 3: interview with representative from Ryedale District Council (main questions)

What was your experience of the 2005 flash flood in Helmsley? How were you involved?

What are your responsibilities with regards to flooding?

Did you work with the Environment Agency when responding the flash flood within 2005?

Did they do a good job?

What did the Council do on the day of the flash flood event?

Did you receive any feedback from local residents in Helmsley on how they had been affected, and what they were doing to try to respond to that?

Have you had any contact with local residents in Helmsley about flooding? Are you aware if they have done anything to respond to flooding?

What factors make people do something to protect their houses from flooding?

Do you get any feedback from local people passing on their knowledge and experience of flooding to you?

Do you have good enough resources and expertise to deal with flooding?

Is there any kind of work occurring to deal with flash flooding in Ryedale?

Do you think that land management is a major cause of flooding in Ryedale?

Do planning policies, in relation to flooding, come into Ryedale district at all?

What do you think is the best thing for people to do to protect their houses from flooding and respond to flooding?

As a Council, have your responsibilities and the way you go about your business changed after the Pitt Review[1]? What implications does the Pitt Review have for you as a council?

How do you feel about the responsibilities being passed on to you?

Do you think that a flash flood event is more difficult to deal with and respond to, compared with traditional lowland river flooding?

What are the best ways that people can cope with flash floods and respond to them in the long term?

Is flooding getting worse across the country?

Do you think that climate change is a major factor in flood risk across the country?

Is river maintenance a potential cause of flooding?

How well can the council respond to flash flooding in particular?

Do you think that people are taking measures to make themselves more resilient to flash floods?

Document/reference mentioned within above text: [1] – Pitt, 2008

Appendix 2

Questionnaire

This appendix contains a copy of the postal questionnaire sent to all identifiable addresses within Helmsley.

Flooding and heavy rain in Ryedale - questionnaire

Your details:
(**Please note**: these details will remain confidential and will not be passed on to any third party)

Your age:
Sex: Male / Female
How long have you lived in the Ryedale area for (years):
Occupation:
How many people live in your house? Adults: [ ], children: [ ]

Your address:

Section 1: Flooding in upper Ryedale

Mark on the timeline below when a flood has occurred on the River Rye (i.e. the Rye has risen over its banks, close to where you live).

Mark the flood with a **dot** if you *witnessed or experienced the flood yourself*, and also note the year and month/season of the flood, if you can remember them.

Mark the flood with a **cross** if you have *heard of the flood through word-of-mouth, your own research or any other means* (including floods that have occurred before you lived here), and also note the year and month/season of the flood, if you can remember them.

If there are any other floods on the river Rye which you have heard of (e.g. any that occurred before 1920), please note them below the timeline.

In your opinion, what is the likelihood that parts of the following locations will experience flooding in the next ten years? (**tick one box per location**)

Location	Very low	Low	Medium	High
Pickering town centre				
Upper Ryedale (Helmsley, Rievaulx)				
central York				
Your own house				

Please indicate whether or not you agree or disagree with the following statements (**tick one box for each question**)

	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Flooding of the River Rye is getting worse					
Flooding from other streams in Ryedale is getting worse					
Surface-water flooding (water running off the land) in Ryedale is getting worse					
Across the country as a whole, flooding is getting worse					
The flood which occurred in Ryedale in June 2005 was a one-off event and will not happen again					
Flooding in Ryedale will occur more frequently in the future					
If a similar flood to that in 2005 occurred again, **people who are likely to be affected** are prepared to deal with it					
If a similar flood to that in 2005 occurred again, the **local authorities** are prepared to deal with it					

If you ticked the box 'Strongly disagree" or "Disagree" for either of the last two questions, please briefly explain why here:

Below is a table with a list of some services provided by the Environment Agency which are related to flooding. Please indicate which of the following statements best describes your views on the services (**tick one box per service, related to the statements listed below**)

1 I have never heard of this before
2 I have heard of this, but am not sure what it is
3 I have heard of this and know what it is
4 I have used this service before

Service	statement 1	statement 2	statement 3	statement 4
Flood warning symbols				
Floodline (telephone warning service)				
Flood risk maps				

Have you ever experienced, or been affected by, flooding before 2005? (**circle one**)

Yes No

Did you personally witness the flood in Ryedale in June 2005? (**circle one**)

Yes No

Were you affected by the Ryedale flood in June 2005? (**circle one**)

Directly (e.g. possessions damaged by flood waters)

Indirectly (e.g. changes to local economy and your own wealth/standard of living, insurance premiums rising due to flooding)

No

Do you have any friends or relatives (or know anyone else) who was directly affected by the June 2005 flood? (**circle one**)

Yes No If yes, who? (**circle one**) Friends Relatives others

Since the flood in 2005, have you discussed flooding with other residents? (**circle one**)

Yes No

Were you involved in any way with the cleanup after the June 2005 flood? (**circle one**)

Yes No

Has surface water flooding (water running off the land) affected your house before? (**circle one**)

Yes No

Section 2: Rainfall in upper Ryedale

For each decade listed in the table below, indicate how wet or dry you remember that decade to be, in terms of the amount of rain which fell.

Try to fill in all decades since you have lived in the area, but if you have any opinions about decades before then feel free to comment on those as well (**tick one box per decade**)

Decade	Very dry	Drier than average	About average rainfall	Wetter than average	Very wet
2000s					
1990s					
1980s					
1970s					
1960s					
1950s					
1940s					
1930s					

Over the years you have lived in Ryedale, how has the amount of rainfall that has fallen in each season changed? (**tick one box per season**)

Season	Have got much drier	Have got drier	No noticeable change	Have got wetter	Have got much wetter
Winters					
Springs					
Summers					
Autumns					

Since you have lived in Ryedale, which years have seen the highest amount of rainfall? (**note the three wettest years below**)

Wettest year:	
2nd wettest year:	
3rd wettest year:	

Aside from the rainstorm in June 2005, can you remember any other days in Ryedale which saw a very large amount of rainfall? Please note the year and season/month/date when they occurred, if you can remember these details. (**note as many details of each date as you can below**)

In your view, do the following types of rainfall/precipitation occur more or less often than they used to? (**tick one box per rainfall/precipitation type**)

	Occurring much less often	Occurring less often	No change	Occurring more often	Occurring much more often
Snowfall					
Prolonged rainfall (lasting over a day)					
Intense, heavy thunderstorms					

Section 3: Your views on flooding and rainfall

Please respond to the statements below. (**tick one box per row**)

Since the flood in 2005, are you…	No	Yes, a little	Yes, a lot
…more aware of weather forecasts than you used to be?			
…more aware of river and stream levels than you used to be?			

This is an open section. If you have any thoughts related to the question below, or want to expand on other answers or have any other thoughts on flooding, please use this page.

What factors contributed to the flood in Ryedale in 2005? Has anything occurred to increase the risk of flooding?

Appendix 3

Variables used within the questionnaire analysis

This appendix lists the variables involved in the questionnaire analysis. These are divided into seven different variable classes (as described within Section 3.8.2). Respondents' answers to questions were separated into different response categories for analysis, as described in the 'Response categories/information' column.

Variable	Variable classification	Data form	Response categories/information
Age	Demographic	Numeric	Age.
Years lived in Ryedale	Demographic	Numeric	The number of years that a respondent has lived in Ryedale, as reported in the questionnaire. If respondent gave the year that they moved to Ryedale, then that year was deducted from 2009 (the year the questionnaire survey was carried out) to give the number of years that the respondent had lived in Ryedale.
Children living in house?	Demographic	Categorical	*Yes / No*, based upon questionnaire response (respondents were asked to provide the number of children living at home)
More than one adult living in house?	Demographic	Categorical	*Yes / No*, based upon questionnaire response (respondents were asked to provide the number of adults living at home)
Gender	Demographic	Categorical	*Male / Female*.
Work	Demographic	Categorical	*Retired / In Work*. Based upon questionnaire responses - if any job or career was listed, then this was presumed to be 'in work'.
Distance of house from river	Location	Numeric	The distance from the respondent's house to the River Rye as assessed using ArcGIS. Only calculated where questionnaires had given an exact, identifiable address.
Within flood risk zone 3?	Location	Categorical	*Yes / No*. ArcGIS assessment of whether the respondent's house was located in the area assessed by the Environment Agency as having a 1 in 100 risk of flooding, or greater (Flood risk zone 3)[1]. Only calculated where questionnaires had given an exact, identifiable address.

Variable	Variable classification	Data form	Response categories/information
Flooding (location) is getting worse Locations: • '...of the River Rye...' • '...from other streams in Ryedale...' • '...Surface-water flooding (water running off the land) in Ryedale...' also • 'Across the country as a whole, flooding is getting worse' (Four variables)	Flood risk perception	Categorical	Respondents were asked to give an opinion on the statements. The questionnaire gave five possible responses from 'Strongly disagree' to 'Strongly agree'. For analysis, responses were combined into three categories - *Agree, Neither agree nor disagree, Disagree*.
The flood which occurred in Ryedale in June 2005 was a one-off event and will not happen again	Flood risk perception	Categorical	Respondents were asked to give an opinion on the statement. The questionnaire gave five possible responses from Strongly disagree to Strongly agree. For analysis, responses were combined into three categories - *Agree, Neither agree nor disagree, Disagree*.
Flooding in Ryedale will occur more frequently in the future	Flood risk perception	Categorical	Respondents were asked to give an opinion on the statement. The questionnaire gave five possible responses from 'Strongly disagree' to 'Strongly agree'. For analysis, responses were combined into three categories - *Agree, Neither agree nor disagree, Disagree*.
Perceived likelihood of flooding in: • Pickering • Upper Ryedale • York • your own house in the next 10 years (Four variables)	Flood risk perception	Categorical	Respondents were asked "In your opinion, what is the likelihood that parts of the following locations will experience flooding in the next ten years?" The questionnaire gave four possible responses – 'Low', 'Medium', 'High', 'Very High'. For analysis, responses were combined into three categories - *Low, Medium, High*. The locations were given as 'Pickering town centre', 'Upper Ryedale (Helmsley, Rievaulx)', 'central York', and 'Your own house'

Variable	Variable classification	Data form	Response categories/information
Knowledge of: • flood warning symbols • Floodline (telephone warning symbols) • flood risk maps (Three variables)	Flood response	Categorical	Respondents were asked to give their views on services provided by the Environment Agency. The questionnaire gave four possible responses - 'I have never heard of this before' 'I have heard of this, but am not sure what it is' 'I have heard of this and know what it is' 'I have used this service before' For analysis, responses were combined into two categories - *Does know what this is*, and *Does not know what this is*
Since the flood in 2005, have you discussed flooding with other residents?	Flood response	Categorical	*Yes / No*.
Since the flood in 2005, are you: • more aware of weather forecasts than you used to be? • more aware of river and stream levels than you used to be? (Two variables)	Flood response	Categorical	The questionnaire gave three possible responses – 'No', 'Yes, a little' and 'Yes, a lot'. The two yes responses were combined to form *Yes / No*.
If a similar flood to that in 2005 occurred again,: • people who are likely to be affected are prepared to deal with it • the local authorities are prepared to deal with it (Two variables)	Flood response	Categorical	Respondents were asked to give their opinions on the statements. The questionnaire gave five possible responses from 'Strongly disagree' to 'Strongly agree'. For analysis, responses were combined into three categories - *Agree, Neither agree nor disagree, Disagree*. Respondents who answered either 'Strongly disagree' or 'Disagree' within the questionnaire were asked to briefly explain why.

Variable	Variable classification	Data form	Response categories/information
Were you affected by the Ryedale flood in June 2005?	2005 flood experience	Categorical	Three responses: *Directly affected* (possessions damaged by flood waters)[2] *Indirectly affected* (changes to local economy, personal standard of living, insurance premium change due to flooding)[2] *No*
Did you personally witness the flood in Ryedale in June 2005?	2005 flood experience	Categorical	*Yes / No*.
Do you have any friends or relatives (or know anyone else) who was directly affected by the June 2005 flood?	2005 flood experience	Categorical	*Yes / No*, based upon responses given.
Do you know any: • friends who were directly affected? • relatives who were directly affected? • others who were directly affected? (Three variables)	2005 flood experience	Categorical	*Yes / No*. Respondents were asked to specify people who they knew in the above question.
Were you involved in any way with the cleanup after the June 2005 flood?	2005 flood experience	Categorical	*Yes / No*.
Total number of floods recalled	Overall flood experience	Numerical	The total number of floods recalled by the respondent within the questionnaire. This was based predominantly on the timeline indicated on the questionnaire. Other floods mentioned in the questionnaire, such as answering questions about the 2005 flood, were also counted as recalled floods.
Total number of floods recalled, 1990s and 2000s	Overall flood experience	Numerical	Same as above, a sum total of floods within the 1990s and 2000s periods.
Have you ever experienced, or been affected by, flooding before 2005?	Overall flood experience	Categorical	*Yes / No*.

Variable	Variable classification	Data form	Response categories/information
Has surface water flooding (water running off the land) affected your house before?	Overall flood experience	Categorical	*Yes / No*.
Perceived wetness of: • 2000s • 1990s • 1980s • 1970s • 1960s • 1950s • 1940s • 1930s (Eight variables)	Rainfall change perception	Categorical	Questionnaire respondents were asked to "...indicate how wet or dry you remember that decade to be, in terms of the amount of rain which fell" for all decades they could. The questionnaire gave five possible responses from 'Very dry' to 'Very wet'. For analysis, responses were combined into three categories - *Drier than average, about average rainfall, wetter than average*.
Perceived change to: • Winter rainfall • Spring rainfall • Summer rainfall • Autumn rainfall (Four variables)	Rainfall change perception	Categorical	Questionnaire respondents were asked "Over the years you have lived in Ryedale, how has the amount of rainfall that has fallen in each season changed?" The questionnaire gave five possible responses from 'Have got much drier' to 'Have got much wetter'. For analysis, responses were combined into three categories - *Have got drier, No noticeable change, Have got wetter*.
Perceived change in: • Snowfall • Prolonged rainfall • Intense, heavy thunderstorms (Three variables)	Rainfall change perception	Categorical	Questionnaire respondents were asked whether the types of precipitation given "...occur more or less often than they used to". Prolonged rainfall was defined as rainfall lasting over one day in duration. The questionnaire gave five possible responses from 'Occurring much less often' to 'Occurring much more often'. For analysis, responses were combined into three categories - *Occurring less often, No change, Occurring more often*.

[1] – as defined as such in Department for Communities and Local Government (2006), page 23

[2] – definitions given approximate those provided by Penning-Rowsell and Chatterton (1977), pages 1-2.

Appendix 4

Statistically significant relationships from the rainfall and discharge analysis

This appendix details statistically significant relationships from the rainfall analysis included in this thesis (Chapters 4 and 5). The following relationships are statistically significant at the 95% confidence level. Data are mostly presented in table form (A4.1). A text summary is given for some of the discharge and rainfall relationships assessed in Chapter 5 (A4.2). Where ‘heavy rain days’ are referred to in the tables, this relates to the DR1 threshold (as defined within the thesis text, and described within Section 3.7.1) unless otherwise specified. Where ‘Decade’ is listed as a variable in the tables, the midpoint of the decade was used for calculation.

A4.1 Tabular summary of statistically significant relationships found within Chapter 4

Thesis section: page	Variables	Period of analysis / n	Test / results	Significance (p-value)
4.1.1: 106	Rainfall variable: Annual rainfall totals (normalised), upper Ryedale series Time period	1961-2009 (n = 49)	Simple regression, linear model (y = a + bx) Correlation coefficient: 0.288406	0.0445
4.2: 119	Annual rainfall totals (normalised), upper Ryedale Annual rainfall totals (mm), Durham	1916-2009 (n = 94)	Simple regression, linear model (y = a + bx) Correlation coefficient: 0.775756	0.0000
4.2: 119	Annual rainfall totals (normalised), upper Ryedale Annual rainfall totals (mm), England and Wales	1916-2009 (n = 94)	Simple regression, linear model (y = a + bx) Correlation coefficient: 0.759035	0.0000
4.2: 123	Proportion of summer rainfall falling on heavy rain days, England and Wales series Time period	1961-2000 (n = 40)	Simple regression, linear model (y = a + bx) Correlation coefficient: -0.368691	0.0192
4.2: 123	Proportion of autumn rainfall falling on heavy rain days, England and Wales series Time period	1961-2009 (n = 49)	Simple regression, linear model (y = a + bx) Correlation coefficient: 0.343598	0.0156
4.2: 125	Winter:summer rainfall ratio, upper Ryedale Winter:summer rainfall ratio, Durham	1917-2009 (n = 93)	Simple regression, linear model (y = a + bx) Correlation coefficient: 0.788555	0.0000

Thesis section: page	Variables	Period of analysis / n	Test / results	Significance (p-value)
4.2: 126	Winter:summer rainfall ratio, upper Ryedale Winter:summer rainfall ratio, England and Wales series	1917-2009 (n = 93)	Simple regression, linear model (y = a + bx) Correlation coefficient: 0.813842	0.0000
4.3: 127	Annual rainfall totals, upper Ryedale Annual rainfall totals, Helmsley	1990-2009 (n = 19)	Simple regression, linear model (y = a + bx) Correlation coefficient: 0.875185	0.0000
4.3: 127	Annual rainfall totals, upper Ryedale Annual rainfall totals, Sproxton	1994-2009 (n = 15)	Simple regression, linear model (y = a + bx) Correlation coefficient: 0.897439	0.0000
4.3: 127	Monthly rainfall totals, upper Ryedale Monthly rainfall totals, Helmsley	January 1990-August 2009, monthly rainfall values (n = 236)	Simple regression, linear model (y = a + bx) Correlation coefficient: 0.825708	0.0000
4.3: 127	Monthly rainfall totals, upper Ryedale Monthly rainfall totals, Sproxton	January 1994-August 2009, monthly rainfall values (n = 188)	Simple regression, linear model (y = a + bx) Correlation coefficient: 0.913617	0.0000
4.3: 127	Annual maximum daily rainfall (mm), upper Ryedale Annual maximum daily rainfall (mm), Helmsley	1990-2008 (n = 19)	Simple regression, linear model (y = a + bx) Correlation coefficient: 0.781979	0.0001
4.3: 127	Annual frequency of heavy rain days, upper Ryedale Annual frequency of days with rainfall greater than 16mm, Helmsley	1990-2008 (n = 19)	Simple regression, linear model (y = a + bx) Correlation coefficient: 0.64624	0.0028

Thesis section: page	Variables	Period of analysis / n	Test / results	Significance (p-value)
4.4: 129	Response rate (% of questionnaire respondents who provided a perception of decadal rainfall) Decade	1930s-2000s (n = 8, 2000s are not a complete decade)	Simple regression, linear model (y = a + bx) Correlation coefficient: 0.954856	0.0002
4.4: 130	Age (mean, of questionnaire respondents who provided a perception of decadal rainfall) Decade	1930s-2000s (n = 8, 2000s are not a complete decade)	Simple regression, linear model (y = a + bx) Correlation coefficient: -0.891893	0.0029
4.4: 130	Years of residence in Ryedale (mean, of questionnaire respondents who provided a perception of decadal rainfall) Decade	1930s-2000s (n = 8, 2000s are not a complete decade)	Simple regression, linear model (y = a + bx) Correlation coefficient: -0.963341	0.0001
4.4: 132	Decadal mean annual rainfall totals, upper Ryedale (normalised) Perceived wetness of decades (derived from questionnaire data)	1930s-2000s (n = 8, 2000s not a complete decade)	Simple regression, linear model (y = a + bx) Correlation coefficient: 0.772428	0.0247
4.4: 134	Age Perceived wetness of 2000s decade	Questionnaire respondents n = 80	Kruskal-Wallis test (non-parametric test) χ^2 = 7.150 Degrees of freedom = 2 Cross-table 1 below.	0.028
4.4: 135	Age Perceived change to summer rainfall	Questionnaire respondents n = 92	Kruskal-Wallis test (non-parametric test) χ^2 = 6.607 Degrees of freedom = 2 Cross-table 2 below.	0.037

Thesis section: page	Variables	Period of analysis / n	Test / results	Significance (p-value)
4.4: 135	Age Perceived change to frequency of intense, heavy thunderstorms	Questionnaire respondents n = 94	Kruskal-Wallis test (non-parametric test) $\chi^2 = 7.239$ Degrees of freedom = 2 Cross-table 3 below.	0.027

Cross-table 1

Perceived wetness of 2000s	n	Mean rank
Drier than average	6	50.75
About average rainfall	18	51.22
Wetter than average	56	35.96

Cross-table 2

Perceived change to summer rainfall	n	Mean rank
Have got drier	5	73.4
No change	25	49.96
Have got wetter	62	42.94

Cross-table 3

Perceived change to frequency of intense, heavy thunderstorms	n	Mean rank
Occur less often	13	46.08
No change	44	55.18
Occur more often	37	38.86

A4.2 Statistically significant relationships between rainfall and discharge found within Chapter 5

Thesis section: page	Variable(s)	Period of analysis / n	Test / results	Significance (p-value)
5.3.2: 183	Annual frequency of high flow events (highest 50 flow events on record), Broadway Foot Annual rainfall totals, upper Ryedale	1978-2009 (n = 32)	Simple regression, linear model (y = a + bx) Correlation coefficient: 0.516860	0.0138

Section 5.4.2
Table showing analysis on page 209

Variables: Rainfall (mm), upper Ryedale series,
Peak discharge ($m^3 s^{-1}$), 50 largest discharge events recorded, River Rye at Broadway Foot

Test: Simple regression, linear model (y = a + bx)
Time period of discharge data: 1978-2009
r^2 and p-values shown below in table form.

Initial dataset of 50 discharge events (recorded within 1978-2009 period) reduced to 42 due to potential snowmelt influence or minimal associated rainfall for eight of the events. Therefore, three datasets of flow events with n = 42, 41, 38.

Peak discharge ($m^3 s^{-1}$)	Rainfall (mm) [Lag method]	Rainfall (mm) [Multi-day rainfall method]
All events (n = 42)	r^2 = 0.235 p = 0.0011	r^2 = 0.18 p = 0.0051
All events except 2005 flash flood (n = 41)	r^2 = 0.163 p = 0.0090	r^2 = 0.267 p = 0.0005
All events except estimated overbank floods (n = 38)	r^2 = 0.143 p = 0.0193	

Section 5.4.3
Table showing analysis on page 212

Variables: Total event rainfall (mm) and peak rainfall rate (mm, 15 minutes), upper Ryedale series,
Peak discharge (m^3 s^{-1}), 20 largest discharge events recorded, River Rye at Broadway Foot (11^{th} September 2004-2009 period)

Test: Simple regression, linear model (y = a + bx)
Time period: 11th September 2004-2009
r^2 and p-values shown below in table form.

Initial dataset of 20 discharge events reduced to 16 due to data issues for four events.

	Peak discharge comparison, all rainfall values (n = 16)
Total event rainfall (mm)	$r^2 = 0.538$ $p = 0.0012$
Peak rainfall rate (mm, 15 minutes)	$r^2 = 0.944$ $p = 0.0000$

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(Appendix G. of Wass et al. (2008) constitutes a review of historical flooding, from which a reference to the Yorkshire Gazette (edition unnamed) is used to identify that a flood occurred in Malton in 1931 (page G.18))

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