The June 2007 floods in Hull

Interim Report by the Independent Review Body
24th August 2007

Professor Tom Coulthard
Professor Lynne Frostick
Harold Hardcastle
Kath Jones
Dave Rogers
Malcolm Scott

Index

Executive Summary

In June 2007, the city of Kingston upon Hull experienced unusually high rain fall. Subsequent flooding caused widespread disruption with damage to 7208 residential and over 1300 businesses. Following the flooding, Hull City Council commissioned an Independent Review Body to examine the key factors leading to the flooding in Hull and to make recommendations for actions to improve flood prevention in the future. The review body were asked to prepare an interim report in August 2007 and a final report in November 2007.

Our key findings are:

- **Hull flooded because the drainage system was overwhelmed.**
- **Given the magnitude of the storm (greater than 1 in 150 years) we feel it is very encouraging that key pieces of important civil infrastructure did not fail.**
- **Hull's trunk sewer system is modern compared to other UK historical cities.**
- **We have significant concerns as to whether the pumping system, that was re-evaluated for the Humbercare project (post 2000), is correctly designed to cover a 1 in 30 year storm event.**
- **Hull's low lying position increases its vulnerability. Therefore, we recommend that Hull should have additional levels of protection above and beyond a 1 in 30 year storm event.**
- **The availability of additional pumping would increase capacity, provide backup and contingency should any of the existing pumps fail.**
- **There were no contingency plans for the failure of Bransholme pumping station or appropriate protection from flood water.**
- **Blocked gullies appear not to have been a major factor in causing general flooding.**
- **There was no list of key strategic locations and infrastructure (e.g. pumping stations, substations etc..) agreed by the agencies**
- **No single agency (e.g. Yorkshire Water, Environment Agency, Hull CC) accepts responsibility for any elements outside their own terms of reference nor have they historically allowed others to influence their own obligations. This is a recurring theme - one of inadequate consultation, co-operation and unity between the agencies.**
- **There is presently no rainfall flash flood warning system.**

Our recommendations are:

- **For urban drainage, designs based on industry standards to protect from a 1 in 30 year storm event may be inadequate. Additional capacity should be factored in for climate change.**
- **We recommend that the EA explore expanding the Floodline system to cover all types of flood warnings (rainfall and river).**
- **The flooding in Hull has revealed the difficulties of having multiple agencies responsible for different areas of the drainage system. We feel it is vital that the Environment Agency, Local Authority and Water Company closely co-operate on operation, investment and design.**
- **Agencies should investigate whether flooding in West Hull could be reduced by diverting and pumping water through existing and new watercourses.**
- **We recommend the existing stormwater pumping capacity in Hull be increased.**
- **We recommend that an independent Drainage Board for Hull is set up.**
- **Agencies must agree a list of key strategic locations for protection in flooding emergencies.**

1. Introduction and Context

1.1 The aims of the Independent Review

In June 2007, the city of Kingston upon Hull experienced unusually high rain fall. Subsequent flooding caused widespread disruption with damage to 7208 residential and over 1300 businesses (figures collected 20th August 2007). Unfortunately one person lost his life. Following the flooding, Hull City Council commissioned an Independent Review Body to examine the key factors leading to the flooding in Hull and to make recommendations for actions to improve flood prevention in the future. The Review Body's members, who are all volunteers, include representatives of public sector, private sector and the community sector in Hull. The members are:

- Professor Tom Coulthard, Professor of Physical Geography, University of Hull (Chair)
- Professor Lynne Frostick, Deputy Head Department of Geography, University of Hull
- Malcolm Scott, Partner, Scotts Property LLP
- Harold Hardcastle, Divisional Director, ARCO
- Kath Jones, Chief Officer, North Bank Forum
- Dave Rogers, Chief Officer, Hull Community and Voluntary Services Ltd

The aims and terms of reference for the Review Body are:

- To enquire into, examine, and form an initial view on the factors which contributed to or exacerbated the flooding of particular areas of the city on this occasion, and affected the nature and scale of the damage and disruption caused by the resulting flood waters.
- To list comprehensively and make clear recommendations on practical actions which should be taken, by each, and all, responsible agencies, to improve flood prevention and response in Hull, in any such future situation of this kind.

The review body were asked to prepare an interim report in August 2007 and a final report in November 2007.

1.2 The scope of this report

The review body first met on the 16th July 2007. Since then we have met 8 times and held a meeting where representatives of the Environment Agency, Yorkshire Water and Hull City Council gave presentations on their roles in the flooding and answered questions form the review body. Members of the body have toured the drainage and pumping facilities of Hull, interviewed present and former employees and acted upon information provided by the public. We have had extensive email, telephone and face to face meetings with representatives of Hull City Council, Yorkshire Water, Humberside Fire and Rescue Service and the Environment Agency.

In our first meeting, the review body agreed to split the review into two sections. For the first part of the review, leading up to this interim report, we decided to concentrate on the physical nature of the flooding. This included addressing important questions such as how much rain fell? Which areas flooded? What caused the flooding? And what may have exacerbated the flooding? We felt it was important to first establish the nature and causes of the flooding. In the second phase of this review, following this report, we will continue to address these questions but focus more on the impact of the flooding on the population of Hull and how the impacts could be mitigated and relief efforts be improved.

In this report, firstly we outline the physical facts of the levels of rainfall that fell, areas that flooded and the history and unique location of Hull. Then we have four sections that

review how the main agencies operated during the flooding (The Environment Agency, Hull City Council, Humberside Fire and Rescue Services and Yorkshire Water), followed by a section reviewing how they operated together through the emergency command structure of Silver Command and how this compared to a previous flooding emergency training exercise. We then draw together from these reviews a series of issues and questions that we feel are important. Finally, we make recommendations for: immediate action, for further study and for the next phase of this review body.

This document is based upon information from the agencies involved, that volunteered by members of the public and from our own sources. We are very grateful for everyone's wholehearted co-operation in this review. We acknowledge that there may be data that we are unaware of and would like to stress that no information deemed important has been deliberately omitted. This report is based on the best information made available to us. Finally, this is an interim report and it covers only the administrative area of Hull City Council, not the East Riding. Comments from the IRB are indicated in bold text coloured blue.

1.3 The catchment and geography of Hull

The City of Hull is low lying, with over 90% of its area lying below high tide level (see Figure 1). Large parts of Hull are built upon reclaimed marshland and some areas (notably East Carr and Orchard Park) are below sea level. To the west of the City the outlying villages of Cottingham and Hessle are situated upon higher ground that drains eastwards into the City of Hull. Though these areas of the East Riding are not covered in this review, they are important as they contribute to the catchment area of Hull. By catchment we mean the areas that drain into the city of Hull, including areas within city itself.

Due to its low elevation the drainage system of Hull is entirely pumped. Prior to 1949 it consisted of a large number of open drains that were largely gravity driven, with tidal gates at drain outlets that closed at high tides. This prevented outflow from the drains into the Humber and led to problems with flooding. In the 1950's, 60's and 70's the drainage and sewerage system of Hull was comprehensively overhauled with a system of gravity fed trunk combined effluent and storm water sewers replacing nearly all of the surface drains. These sewers were emptied by two large pumping stations at West Hull and East Hull.

As a result, compared to other historical UK cities, Hull has a modern sewage and drainage infrastructure. As this system is combined, it led to untreated sewage being pumped into the Humber at West and East Hull. To partially resolve this condition, from 1996 to 2001 Yorkshire Water developed and implemented the 'Humber Care' system that saw the construction of a 10.5 km trunk sewer running across the city from the West Hull pumping station, linking East Hull and on to a new sewage treatment works at Saltend. Gravity fed, flowing from west to east, under non storm conditions this link allows Saltend to treat all the effluent from West and East Hull. Some pumping capacity is retained at West and East Hull for storm conditions.

The exception to the above is Bransholme which has its own storm water drainage system. Constructed in the 1950's, a pumping station discharges water directly into the River Hull, with the option to store water in a lagoon during high river flows. Sewage was treated at this site, but is now transferred to Saltend for processing. No water, apart from that discharged from Bransholme, is pumped into the River Hull.

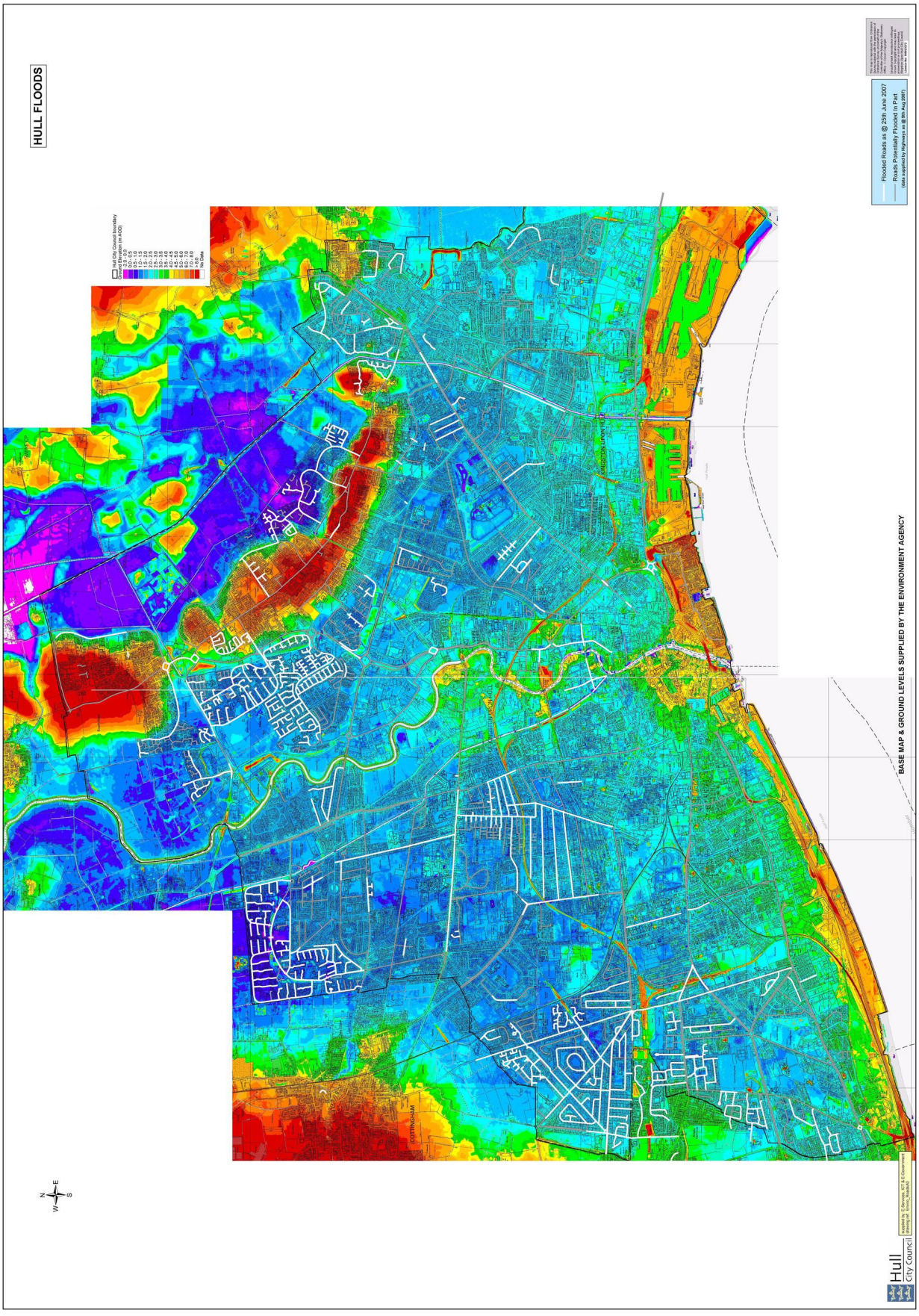

Figure 1.1 Elevation map of Hull also showing roads flooded (Source HCC and EA).

The floods of the 25th of June occurred during neap tidal ranges. We are not sure what the impacts of a high tide may have been upon the floods. All the pumps can operate even during spring or surge tides but the impacts on groundwater levels and the River Hull on Hull's drainage system have not been assessed here. This requires further research.

The organisation and management of the catchment of Hull is split between multiple agencies. The Environment Agency is responsible for all open bodies of water - herein referred to as ***watercourses***. They are also responsible for river and tidal flood defence. Where watercourses are culverted or flow underground they are largely the responsibility of Yorkshire Water, who are also responsible for the ***sewers***. Feeding into the sewers at street level are a system of ***gullies.*** They are the responsibility of the council (when on a public road or council land) or the landowner/homeowner (when on private land - including tenfoots). To clarify, throughout the rest of this report we shall use the terms ***watercourses***, ***sewers*** and ***gullies*** - and these are the responsibility of the Environment Agency, Yorkshire Water and the Council/Homeowners respectively. Additionally, sewerage refers to infrastructure (e.g. the pipes) carrying sewage.

1.4 The unique location of Hull

Its low elevation and reliance upon pumped drainage place Hull in a unique position compared to other UK cities. Whilst all major UK conurbations can be liable to flooding caused by heavy rainfall, Hull is especially vulnerable, as it has limited natural methods of drainage. Its reliance on pumping increases its vulnerability to flood damage should the pumps malfunction of fail. Furthermore, due to its low elevation Hull is also vulnerable to tidal flooding. Hull has significant and effective flood protection defences but these are designed to protect from flooding from the River Hull or from tidal flooding breaching estuary defences.

There are different traditions working side by side when it comes to understanding risk. For instance, engineers and scientists often work on the basis that: risk = cost x hazard. Social scientists' work on adaptive hazard mitigation, which by contrast defines risk= (vulnerability/resilience) x hazard. For vulnerable places such as Hull, attention to vulnerability and resilience is important. Vulnerability is the tendency for something or someone to be damaged. Resilience is the opposite of vulnerability and refers to the capability of something or someone to resist or recover from damage. These aspects will be covered in more detail in the second part of this review.

1.5 Rainfall in June 2007

June 2007 was the wettest month recorded in Yorkshire since 1882 (EA). On the 25th June 2007, a deepening depression became slow moving over the UK, bringing in particular sustained heavy rain to Lincolnshire, Yorkshire and the Midlands which resulted in widespread flooding across the Northern UK. There are several records of rainfall from that day including 96mm at the River Hull in Hull (EA) and c.105mm at Saltend (Yorkshire Water). The Geography Department at the University of Hull has an uncalibrated rain gauge and its measurements for June are shown in Figure 2 and for the 25th of June in Figure 3. These show that over 250mm fell in the June, with over 70mm falling on the 15th June and over 110mm on the 25th June. The record also shows that rainfall on the 25th was heavy and sustained (Figure 1.3), with rainfall intensities of over 6mm an hour from 8am to 5pm. We have no data on soil moisture or saturation levels, but it is highly likely that many areas of Hull were already significantly surcharged with water prior to the rain on the 25th.

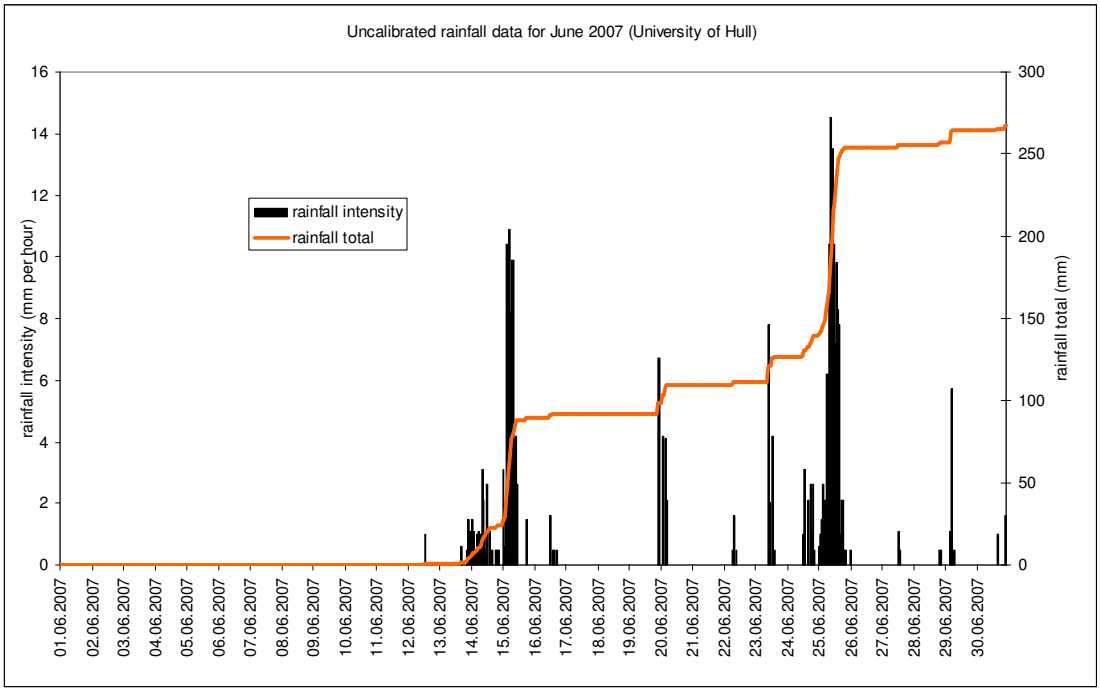

Figure 1.2. Rainfall over Hull for June 2007. Data from an uncalibrated rain gauge on the Cohen Building, University of Hull.

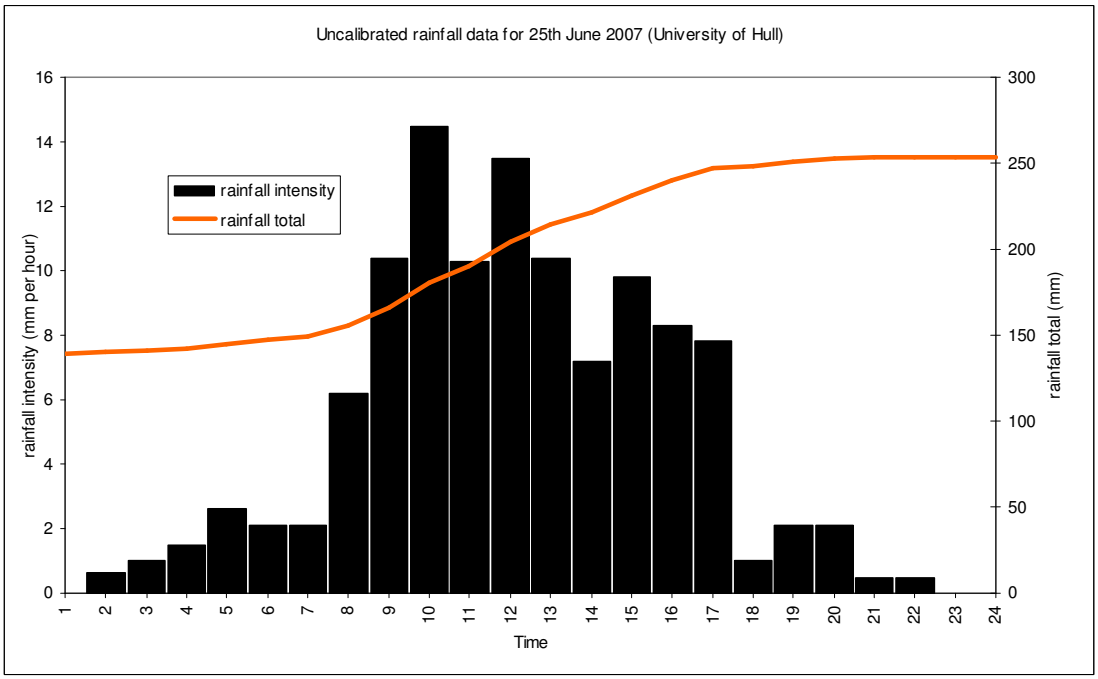

Figure 1.3. Rainfall over Hull for 25th June 2007. Data from an uncalibrated rain gauge on the Cohen Building, University of Hull.

There is some uncertainty surrounding the 'return period' of the 25th June rainfall event, that is the probability - or likelihood that such an event will happen. Referring to the Centre for Ecology and Hydrology (CEH) flood estimation handbook, the event would have a probability of 1 in 150 years (source Yorkshire Water), though some media sources have quoted figures in excess of 1 in 200 years. To place these figures in context, Table 1 details statistics of historical rainfall maxima from the UK. This indicates that whilst the rainfall in June 2007 was unusual, there have historically been considerably larger quantities of rainfall recorded falling in shorter times. At this point we would like to note that the term such as '1 in 100 year event' does not mean that a rainstorm of this magnitude will

occur every 100 years. It means that the probability of one occurring is 1 in 100, or 1% per year. It is completely possible for two 1 in 100 year storms to follow each other. Furthermore, these return period probabilities are built by analysing previous rainfall events and are therefore reliant upon having an accurate and historically long record. For example, it is hard to predict with confidence what a 1 in 100 year event will be if the prediction is only based on 30 years of data.

Highest 5-minute Total: 32 mm at Preston, Lancashire, 10th August 1893
Highest 30-minute Total: 80 mm at Eskdalemuir, Dumfries and Galloway, 26th June 1953
Highest 60-minute Total: 92 mm at Maidenhead, Berkshire, 12th July 1901
Highest 90-minute Total: 117 mm at Dunsop Valley, Lancashire, 8th August 1967
Highest 120-minute Total: 193 mm at Walsaw Dean Lodge, West Yorkshire,19th May 1989
Highest 180-minute Total: 178 mm at Horncastle, Lincolnshire, 7th October 1960
Highest 24-hour Total: 279 mm at Martinstown, nr Dorchester, Dorset, 18th July 1955

This Report: 12 hour total: 70mm University of Hull, Hull. 15th June 2007.
This Report: 24 hour total:.110mm University of Hull, Hull. 25th June 2007

Table 1.1. UK rainfall statistics (Met Office: http://www.metoffice.gov.uk/corporate/library/factsheets/factsheet09.pdf) and figures from this report.

1.6 The extent of flooding

During and following the heavy rain there was widespread flooding across the city of Hull. Ascertaining a precise map of where was flooded has proved difficult. There are no suitable satellite images for Hull on that day of sufficient detail but there are limited oblique aerial photographs of certain areas of Hull taken by the British Geological Survey on the 26th June. During the flooding, the City's extensive CCTV system proved vital for identifying roads and areas that were flooded. Based on this and data from council operatives the ***roads*** flooded are shown as white areas in Figure 1.

Based on this information the number of houses in roads affected by flooding were initially estimated at 14 000. In the weeks following the floods, council operatives carried out door to door surveys to establish whether properties had been flooded or not. Figure 4 shows the location of properties recorded as being flooded (water above the floor) as of the 20th August 2007. There were large areas of standing water in many other parts of the city, especially in open or park land and this is not shown in Figure 1 or 4. As such, these maps probably represent an underestimate of the areas inundated.

The patterns of flooding indicate that in East Hull flooding was largely concentrated around the areas of Bransholme and Kingswood that have a separate drainage system. There are other smaller areas of flooding including the very low areas by East Carr. Flooding was more extensive in West Hull with large areas of Orchard Park, Newland Avenue, the Avenues, Priory Road/East Ella and Anlaby Park flooded. Comparing the areas that were flooded to the elevation in Figure 1, very low areas flooded (Orchard Park, East Carr, Chanterlands Avenue railway bridge) but flooding was not restricted just to the lowest areas of Hull. Some low lying areas were flooded, whilst others were not. This indicates that topography and elevation was not the only control on flooding in Hull City.

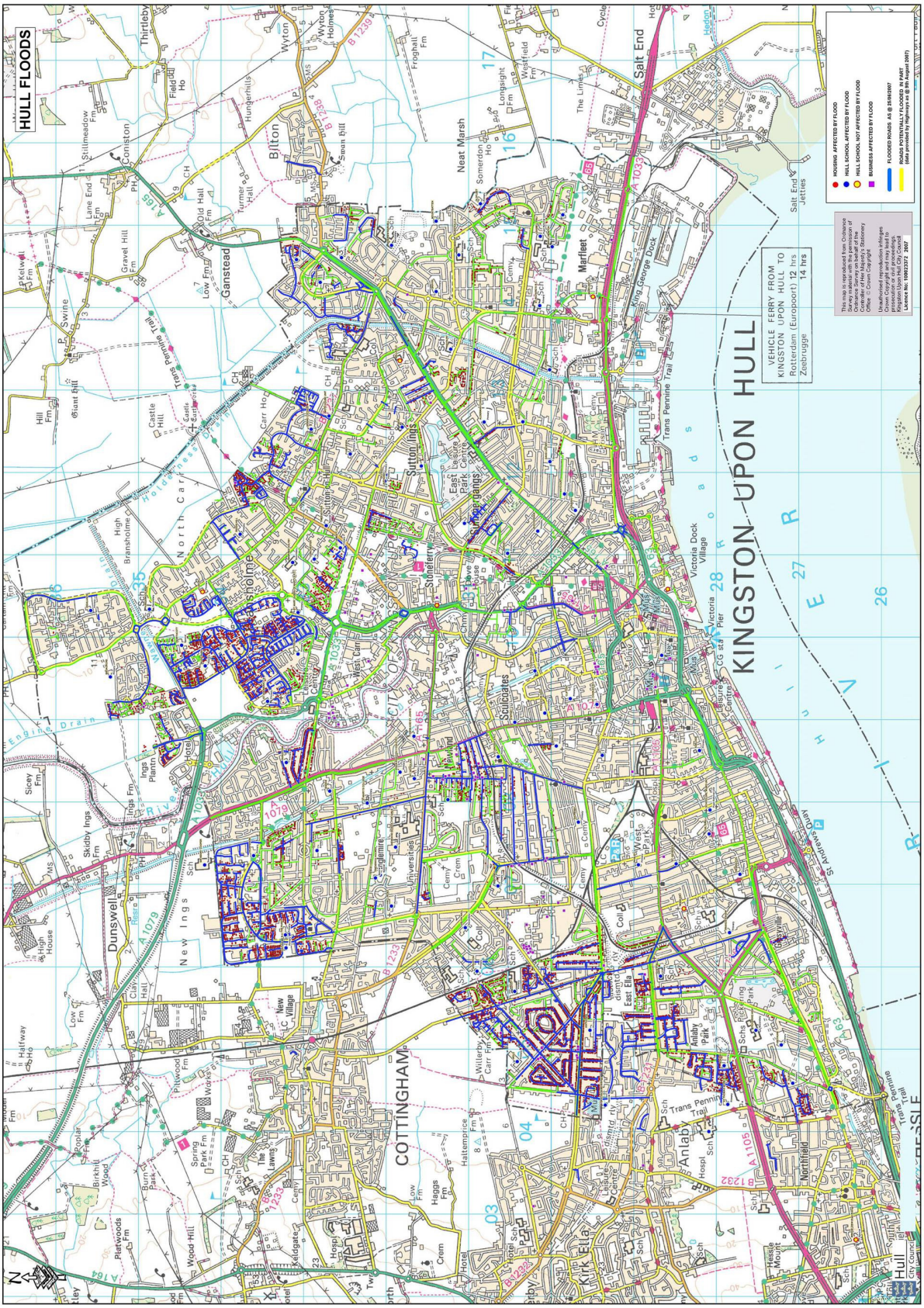

Figure 1.4. Map of hull showing roads and properties flooded.

2. The Environment Agency

2.1 The roles of the Environment Agency:

The Environment Agency (EA) has specific responsibilities for river and tidal flooding. These include mapping the likely extent of floods, develop procedures to prepare for flooding emergencies, liaising with local authorities and the emergency services, and running and taking part in training exercises. Furthermore, they maintain existing defences against river and tidal flooding and provide new flood defences where these are technically, economically and environmentally feasible. Additionally the EA provides advice to local authorities regarding planning.

During a flooding emergency, the EA has more specific roles. These include working closely with the Met Office to forecast what impact rainfall may have on local river levels and to subsequently warn the public, local authorities and emergency services when river levels may cause flooding. During a flood the EA has an important role in the emergency response advising civil emergency response (Gold and Silver Command) as well as directly helping and advice on pumping operations.

2.2 Events surrounding the flooding on the 25th June according to the EA

On Sunday 24th June, the Met office issued a weather warning, that was discussed with flood warning duty officers, and flood watches were sent out to the EA's professional partners in the Yorkshire Dales and Ridings regions. A 24 hour flood incident room was also started on Sunday evening. On Monday morning and through the afternoon, it rained heavily across the region. Local rain gauges reported totals for the 25th June of 96mm in Hull (River Hull), 81mm in Pickering (Pickering Beck), 88mm in Penistone (River Don) and 70mm in Leeds (River Aire). Local rivers were high and groundwater levels in the Wolds rose by an unexpected 10m in 24 hours. Records indicate that June was the wettest month in Yorkshire since 1882. In the City of Hull, no watercourses over topped except Setting Dyke to the west of the city that overtopped on the afternoon of the 25th and there was some minor overtopping of the Holderness Drain east of the City. The River Hull did not overtop its banks at any point.

The Environment Agency concluded that Hull's' drainage system could not accommodate the level of rain water, leading to drains backing up and overflowing. The drainage system in Hull is complex and several of Hull's open watercourses flow directly into the main sewer system. These include Setting Dyke flowing into the sewer on National Avenue, Cottingham Drain into the sewer on Cottingham Road and Wanlass Beck into the sewer at the western end of Bricknell Avenue. In Hull itself there were no reports of blocked watercourses. It appears that as the sewers were full to capacity and the watercourses had no-where to drain to. This may not be the case for all parts of East Yorkshire.

EA personnel were present at Silver Command in Hull and provided important real time information on river levels and likely danger areas. Discussion with representatives from the Council and Humberside Fire and Rescue indicate that the EA were invaluable in providing accurate and vital information on river levels, tides, and weather forecasts. In particular, they established a close working relationship with Humberside Fire and Rescue Services on pumping operations, though there were difficulties as there was nowhere to pump water to, because watercourses and drains were full to capacity.

The IRB believe that temporary storage areas which water could be pumped into should be identified for future plans. This may include park or recreational areas.

2.3 Flood warning

The EA has a system to warn residents from river and tidal flooding. Subscribers to the floodline can receive automated telephone calls informing them of danger from flooding. However, the flood warning system in Hull and across the UK is only designed to deal with the threat of coastal, estuarine or river flooding. There is no provision for warning from events such as the 25th that were a result of pluvial flooding - that caused by heavy rainfall.

The IRB are concerned that no agency seems to have responsibility to provide warning from pluvial (rainfall related) flooding. A warning system for flash floods should be developed. This will require policy change at a national level.

3. Hull City Council

3.1 Statutory responsibilities of Hull City Council

The Civil Contingencies Act 2004 establishes roles and responsibilities for those involved in local emergency preparation and response. The Act divides local responders into two categories. Those in Category 1, the emergency services, the Local Authority and some NHS bodies are the core of the response to most emergencies.

Inter-agency working at Silver Command is separately dealt with in section 5. Specifically, Hull City Council's own reaction is framed by five emergency response documents:

- The Emergency Management Arrangements
- The Flood Response Plan
- Procedures for the Management of Rest Centres
- Emergency Control Centre Procedures
- Incident Management Procedures

Copies of all five documents have been made available to the Review Body and we are satisfied with their procedural content.

However, IRB's recommendation is that event learning should be shared within and between agencies at the earliest opportunity. The Council's five Emergency Response documents should be reviewed by all concerned and the possibility of a shared Emergency Response Handbook explored with other agencies.

3.2 Sequence of events

An early warning of heavy rain was issued by the EA on 22 June at 15.11 hours followed by a repeat warning at 11.09 hours on 23 June indicating heavy rain from 15.00 hours Sunday 23 June. A further warning received 16.00 hours on 23 June putting the forecast rain back from 15.00 to 21.00 hours on Sunday 24 June. A flood watch alert was issued at 10.57 hours on 24 June and at 13.40 hours the Council received a fax regarding a flood warning on low lying land in the East Riding. A Major Incident was declared by the City Council at 09.30 hours on 25 June following reports from Area Management Teams and the Police of flooding across the city.

Surprisingly, an immediate requirement raised by the flooding was the critical baseline information on the ownership of current watercourses, whether or not they are pumped and their maintenance regimes, as it did not exist at the time. This information was also relevant to the Review's discussions on drainage, sewers and gullies. What emerged to the Review in relation to this issue (as with a list of strategic assets) was a complex set of relationships of responsibility between Agencies, largely as a result of the history of differing national and local infrastructures, with no sole agency or combined body responsible for holding overall control.

The EA, YW, ERYC and Hull City Council must provide and share data, and baseline information on the ownership of current watercourses as a matter of urgency, certainly by no later than the end of September 2007. Responsibilities should be reviewed and, where possible, rationalised as early as practical thereafter.

In addition a major public communication campaign around practical storm awareness and preparedness issues should be developed and the different agencies roles and responsibilities should be made clearer to the

public. A joint agency public communication strategy needs to be developed, and regular radio bulletins issued during the course of any future events. Statements should come direct from Silver/Gold command.

An abridged log from the Tactical Incident Room shows events subsequently.

Issue	Time
Monday 25 June	
Major Incident declared by City Council	09.30
Incident Room set up at The Guildhall	09.50
All non essential Streetscene Services deployed to sandbagging/road closures	09.50
Ennerdale Sports Centre designated Rest Centre	09.50
Police declare a Major Incident and Silver Command	10.25
City Hall designated as back-up Rest Centre	11.15
Radio report of evacuations - unfounded	12.50
Fire Brigade designated lead authority by Silver Command	13.40
Ennerdale Sports CentreSport centre flooded – City Hall now Rest Centre	15.05
All hospitals declared a state of emergency	19.40
Tuesday 26 June	
Second Rest Centre prepared at The Guildhall	09.13
Incident Room transferred to Festival House	10.30
Army deployed to assist in evacuation	14.25
HRI and Castle Hill confirmed operating only A&E	15.10
City Hall confirmed evacuees at Rest Centre	21.45
Wednesday 27 June	
Confirmation of rooms at Needler Hall, Cottingham for evacuees	07.55
Reduced staffing of Incident Room to minimum	19.30
Reduced staffing at City Hall to minimum	19.40
Thursday 28 June and Friday 29 June	
Operational response continued	
Saturday 30 June	
Evacuation centre for young people established at Gemtec Arena	08.43
Operational staff apart from 2 teams stood down onto standby	16.00
Withdrawal of Fire Brigade staff from the Incident Room	18.30
Sunday 1 July	
Rest Centres standing down - Centre Managers remain on site	06.35
Gemtec Arena Rest Centre closed	17.35
City Hall Rest Centre closed down	21.45
Monday 2 July	
Incident Room stood down	11.30

3.3 Learning lessons

It is important to capture any lessons learnt from that emergency period, not least because the wider impact of public confidence on the general well-being of Hull's communities is crucial. This has already begun through a group of senior Council managers involved in the flood making recommendations for improving the Council's emergency response.

This is welcome, and we were told includes:

- Preparation and Planning – training and testing of emergency responses;
- Emergency Warnings – cascading and escalation;
- Management of the incident during the first 48 hours – clarity on non-essential Council activity, infrastructure requirements such as telephones and emergency generators, the criteria for moving from Silver to Gold Command, establishment of 'red routes' through the city for emergency vehicle deployment;

- Ongoing management and the transition for incident to recovery to rebuilding -the criteria for moving through the various phases of emergency response;
- Decision-making – the ability to gain rapid procurement decisions appropriately;
- Communications – adequate information to the Call Centre for public information as events unfold, additional land-lines needed for rest centres;
- Use of resources – the need for an audit of physical and technical expertise available within the Council, formal agreements with suppliers for emergency provision of goods at short notice and ensuring data captured appropriately for ease of reporting for Government Office and other bodies; and
- Organisational culture – the need to capture where effective working together and pooling of resources overcame operational difficulties.

The IRB welcome the HCC's initiative and feel it is important to share this learning with other agencies.

3.4 Road Gullies

Immediately following the flooding there was considerable speculation about the potential role of inadequate maintenance of the gully system as cause of flooding. Gullies serve to transmit surface water to the main sewers for release into the River Humber via Yorkshire Waters sewer network. The Council has responsibility for cleaning gullies on adopted roads, and those gullies and tenfoots under the auspices of City Council Housing. It may not be widely known or understood that residential owners and developers also have a similar responsibility and should take consequent action.

The Review received submissions and data on the Council's jetting and cleaning regime for the gully system and litter, detritus and weed control regimes .The aim of the current regime is to attend to all gullies on major routes through the city on two occasions per year and once per year in residential areas, although it is doubtful that this frequency has yet been achieved across all roads in the city.

On the roads that flooded on 25 June there are 13,175 gullies. In the 12 months prior to the earlier flood event on 14 June, 37.6% of them had been cleaned and jetted. Of those 4,952 gullies, at the point of cleaning 0.57% of them were reported as blocked or slow-running by the operator. In the immediate aftermath of 25 June, where gully resources were directed to flooded roads, there were no reported blocked gullies – although this may be a function of them having had a significant volume of water that may have cleared any blockages. There have been no reported requests for additional unblocking support to any of those gullies attended during the intensive gully operations immediately following the flood. Several of the areas flooded (e.g. Newland Ave) had their gullies cleaned within the twelve months previously.

On the available evidence, it seems highly unlikely that the gullies were of any overall significance as a direct cause of flooding, although they may have contributed to local flood impact in specific locations.

The IRB feel that there is clearly a need for an integrated, City-wide gully cleaning and jetting service- irrespective of Council ownership. This should be capable of meeting the requirements of the relevant Code of Practice. It should also have the ability to provide 'at cost' service to owners of private housing and industrial gullies to ensure flood waters are capable of leaving the highways via the gullies at their full capacity.

3.5 Sandbags

The question of sandbags' availability and effectiveness seems to be more a matter of public perception and confidence. They are a comforting presence but may not in practice be the best use of resources or the best localised defence. Again, we received evidence of the scope of works undertaken in making sandbags available but we also heard that often the sandbags were not reaching the most vulnerable, as residents were taking them from the vehicles before they were deployed. There was also some evidence of a lack of public awareness of best use, for example, sandbagging doors but leaving air bricks exposed.

The IRB recommend that the real effectiveness of sandbags as a defence mechanism should be evaluated against other options, for example stormboards. Whilst sandbags continue to be used, additional measures such as the issue of heavy duty plastic sheeting to put behind them should be actively pursued.

4. Humberside Fire and Rescue Service (HFRS)

4. 1. Introduction

HFRS is undertaking an internal review of its involvement and response to the incidents that overlaps the preliminary work of the IRB. HFRS provided a written response to the IRB initial request for information that was presented on 31st July 2007. A further meeting between the Deputy Chief Fire Officer Mazen Khuri MSc, DMS, Director of Performance and Operational Support and the Commission Chairman expanded on the initial statement.

The response of HFRS confirms the exceptional commitment of the Officers and support teams to respond to unprecedented circumstances. The effect was compounded by experiencing two exceptional rainfall events within a period that did not allow the natural water table to recover and the source of water - **pluvial** (rain) rather than **fluvial** (river) for which emergency planning had previously been undertaken.

4.2 Responsibility

According to its website (www.humbersidefire.gov.uk) HFRS requirements are confirmed under the Fire Services Act 2004, Section 1. These provisions relate specifically to fire rather than other rescue services. To service the four unitary authorities of Humberside HFRS has undertaken an organisational restructure from 2004 resulting in the formation of two Area Commands for north and south of the Humber. Three Community Protection Units (CPUs) service each Area Command. Each CPU has a structure of command to assess risk and meet the needs of that CPU area within a Local Performance Plan. These appear logically to concentrate on the fire risk.

The 20th July 2007 press release by HFRS set out sensible provisions in the event of further anticipated severe weather conditions. This confirmed the following priorities:

- Fire and rescue work – fire risks
- Flooding involving life – This includes; children, disabled and the elderly
- Flooding that involves at risk properties – Hospitals, telephone exchanges, power and substations etc.
- Flooding in other properties
- General flooding assistance

Co-ordinating and providing large scale pumping operations is not a Humberside Fire and Rescue Service statutory priority.

The IRB question whether there is sufficient clarity about the role of HFRS and the expectations of HFRS from government, services and the public. We would like to know whether HFRS and the Fire and Rescue Service in general is sufficiently resourced to cope with such responsibilities. Furthermore, is it possible to define responsibilities with greater clarity between services and government agencies?

4.3 Communication

On Friday 15th June demand exceeded 100 calls per hour (calls received rather than attempted) throughout the mid morning period. On Monday 25th June from 06.00 calls for assistance quickly reached a peak of around 100 calls an hour and were sustained for the next fifteen hours. Difficulties were encountered by Kingston Communications and BT in connecting callers to HFRS requiring queuing, call holding and reconnection attempts. 821 calls were received from KC and 360 calls were unable to be answered.

Arrangements to divert calls to less busy Fire and Rescue Services were made with 904 further notifications received by HFRS by fax and email. HFRS administrative staff also handled 255 calls for assistance. HFRS total 3,054 calls in 18 hours.

The HFRS press release of 20th July raised concerns that many calls did not warrant the emergency services. For example it states 'It is not the role of HFRS to provide sand bags'.

The IRB question whether a better appreciation of the priorities and responsibilities of HFRS could reduce inappropriate calls.

Is there a possible contingency should, for example, communication centres be affected, noting the HFRS priority to protect telephone exchanges?

Does the redirection of calls to other Fire and Rescue Services have greater potential to provide reassurance to callers and prioritise action?

Is any Fire and Rescue Service resourced to satisfactorily assess the volume of information in emergencies of this scale to prioritise the response?

4.4 Equipment

On 15th June all pumping appliances were involved at times in all four local authority areas and HFRS personnel worked tirelessly throughout the day ensuring that resources were deployed to best effect. The HFRS High Volume Pumping Unit was deployed in Withernsea. The Water Support Unit operated in West Hull. A reserve of available appliances was maintained at strategic locations to respond to life threatening incidents and fell as low as six appliances during peak demand.

On Monday 25th June all HFRS pumping appliances were deployed. Two High Volume Pump Units were brought in from Northumberland and Durham to attempt to drain Kingswood. By Thursday five further High Volume Pumps from other Services were in operation. On 27th June the Service prevented damage in Hedon and on 30th June a reservoir near Barton was pumped to avoid substantial flooding in the Town. High Volume Pumps were in full operation for several days. The HFRS was unable to prevent the substantial recorded flooding and areas remained flooded, or at risk of flooding from a combination of rainfall, tidal and river sources.

The HFRS pumping capability is an emergency resource beyond the pumping and water discharge operations for foul and surface water operated by Yorkshire water and the Environment Agency. Fire and Rescue Service emergency pumping prevented some flooding and removed water from flooded areas.

Do pumping operations prejudice the HFRS ability to deal with statutory priorities of fire and rescue work – life risks?

5. Silver Command Operation and comparison to 'Exercise Deep'

5.1 Introduction

On 22nd November 2005 the Environment Agency organised Exercise Deep, a multi-agency 'Table Top' event based on the occurrence of a major flood event in Hull and Goole. This exercise was designed to test the preparedness of the various agencies involved to deal with such an event. A number of lessons were learned from this and written up in the final report. The Independent Review Body has made a comparison between the lessons learned then and the way the agencies responded to the 25th June 2007 event. One major difference which should be noted is that Exercise Deep was based on a tidal flooding event, rather than rainfall flooding.

5.2 Flood Warnings

Exercise Deep revealed a lack of understanding within other agencies of the differences between the EA's different levels of warning (i.e. Flood Watch, Flood Warning and Severe Flood Warning). On this occasion EA issued an early warning of heavy rainfall on Friday 22nd June which was repeated on Saturday 23rd. A Flood Watch Alert was issued at 10.57 on Sunday 24th June and this was followed later by Flood Warnings in relation to the main watercourses. These do not appear to have escalated to Severe Flood Warnings, perhaps reflecting the capacity of the watercourses on this occasion to cope. However this highlights the problem, which appears to be a national one, that no one agency has responsibility for issuing warnings about rainfall flooding.

Furthermore, It is not clear what warnings were actually given to members of the public. It appears that the EA's flood warning system, which is an automated telephone system, does not operate in Hull and is only designed to cover the area in the immediate vicinity of a river. During Exercise Deep Yorkshire Water commented (Para 4.9.2) that a pre-warning by the EA would allow them to initiate emergency procedures earlier.

The IRB are concerned that no one agency has responsibility for issuing warnings about rainfall flooding. This needs to be addressed by central government. Furthermore, can the EA's system be adapted and extended to cover rainfall flooding in a large urban area like Hull?

5.3 Declaring a state of emergency

Exercise Deep revealed a degree of confusion between agencies about whose responsibility it is to initiate a state of emergency and call Silver or Gold Command (see Exec. Summary, Para. 3.2 and others). This appears to be reflected again in the incident log we have seen from Hull CC.

During the 25th there is some confusion as to when the EA warn Yorkshire Water of an emergency and the point at which YW initiated emergency procedures.

The IRB were surprised that given the crucial role of Yorkshire Water in Hull flood defences that as late as 4.19 pm on Monday 25th YW were still asking for a liaison officer with Silver Command.

5.4 Involving the Army

"*A clear message from the military was that although they can help out in a situation, it takes time for them to mobilise, therefore it is best to contact them sooner.*" (Exercise Deep Exec Summary). There was also reference (para 4.3.1) to the fact that "if it is not to save life it will probably cost". Again the incident log of the 25th June reflects some confusion on this. The issue appears to be that, without authorisation at Chief Exec level (i.e. Gold Command) the Army will

charge for their services. The fact that Hull stayed at Silver Command could have prevented the deployment of the Army if they were required.

The IRB note that all concerned need to have better awareness of how and when the Army can be called in and take this factor into account when deciding whether to move from Silver to Gold Command

5.5 Emergency Plans

One of the observations from Exercise Deep (para 5.2.9) was that although many delegates brought along Emergency Plans, very few were referred to or used during the sessions.

5.6 Location of Rest Centres

Para 3.9.6 of Exercise Deep observes that "*some rest centres have been flooded in this exercise; their location needs rethinking.*" This appears to refer to the debrief session on Goole rather than Hull. However the Incident Log from the 25th June reports that at 9.50am on Monday 25th Ennerdale Sports Centre was put on standby as a Rest Centre. By 3.05pm the log reports Ennerdale as unusable due to flooding.

The IRB has concerns that the Emergency Plan designates Ennerdale as the first choice for a Rest Centre given its vulnerability to flooding.

5.7. Protection of Strategic Locations

A briefing paper from Hull County Council states (31st July para. 3.3.2) that "*there was no list of strategic installations to be protected until the worst of the flooding had occurred.*" There is no reference, either in Exercise Deep or in the Incident Log, to any consideration being given to the protection of strategic locations, in particular key pumping locations.

The IRB strongly recommend that a list of key strategic installations to be protected should be a part of Emergency Plans and of any future planning exercises. This should also include Yorkshire Water pumping stations and power supplies

5.8 Participants in Emergency Planning Exercises

We noted some key participants who were not present at Exercise Deep, who in the actual flood event turned out to be key players.

Para. 2.3.3 of Exercise Deep reports "*The EA was disappointed to learn that Transco would not participate. Their arrangement is that they will not participate in exercises unless gas supplies and infrastructure are directly affected.*" There is at least one report in the Incident Log of a major gas leak on Wold Road. The Incident Log indicates that the bus operators played a key role during the height of the crisis in ferrying people around the city. Whilst the rail operator and British Transport Police were included in Exercise Deep, bus operators were not.

From what we have ascertained so far it would appear that very few of the individual participants in Exercise Deep (as opposed to the organisations they represented) were involved in the actual flood emergency of 25th June. This may well be due to high staff turnover in some of the organisations involved.

The IRB are concerned that if it is true that very few of the participants in this actual emergency attended Exercise Deep, it calls into question the value of doing such an exercise every three years, as recommended by

DEFRA. Consideration should be given to increasing the frequency of these exercises. Inevitably, there will be institutional turnover, and staff training programmes should reflect the continuing need to cover flood response situations.

6. Drainage and sewerage (Yorkshire Water)

6.1 History and Background to Hull's drainage system

From the previous sections it is apparent that Hull's drainage and sewerage system was a major factor in the 25th June floods. In order to understand its present day operation, it is first necessary to appreciate its history. Note: throughout this section we refer to pump and pipe *capacities*, these are measured in the volume of water that can travel through them in cubic metres per second (m^3s^{-1}).

6.1.1 Pre 1949

During the late 19th century Kingston upon Hull was drained via a series of surface and culverted water courses which discharged through a number of gravity outfalls into the River Humber. The practice was to construct small egg-shaped sewers which provided storage during high tides when the outfalls became tide-locked; they carried both foul and surface water. The first improvements to the drainage system in West Hull were, as a result of the public health act of 1875, the construction of a pumping station in 1884 which was steam driven. After the 1914/18 war a further pumping station was built to cater for new, expansive housing estates. In the early 1930's it became evident that new schemes of main drainage were necessary. Owing to the outbreak of hostilities plans were delayed and only received formal ministerial approval of the scheme in 1949.

6.1.2: 1949 - 1975

6.1.2.1 Overview

This period saw Hull's surface and foul water sewerage system extensively overhauled. A new fully pumped system was designed and constructed, with Hull split between East and West Hull, with a separate pumping station for each side. We have two maps that detail the sewage network in 1957 and 1972 (Figures 6.1 and 6.2). Interestingly, these historical maps show how the existing sewer network developed, and in particular how between 1957 and 1972 nearly all of the surface land drains were in filled and diverted into sewers.

6.1.2.2. East Hull

In East Hull, the first stages of the scheme were started before the Second World War and completed in 1950. This saw the construction of a pumping station at East Hull in 1947 to allow the pumping of the Holderness Drain at high tide. Further construction saw the development of the Bilton and Northern trunk sewers (running from Hedon Road to East Park).

A second stage of development at East Hull pumping station started in 1968 and was completed in 1972, adding more pumps to the station (to a total of 11) taking the total pumping capacity of the station to 26 m^3s^{-1}. The northern sewer was then extended from East Park to Sutton Fields industrial estate. The construction of the new pumping station and trunk sewer network resulted in the filling in and/or culverting of the many water courses. The pumping station in its final format was fed by 3 sewers namely Bilton, Northern trunk sewers and Drypool trunk sewer. The pumping capacity included standby generation plant to provide reliability. All 3 incoming sewers fed into the new station and the old (1947) station was retained for times of maximum flow. Yorkshire Water now has responsibility for the pumping of the Holderness drain when the water level exceeds 0.3 m AOD. This enabled the Foredyke stream to be diverted into the Holderness drain at Great Culvert.

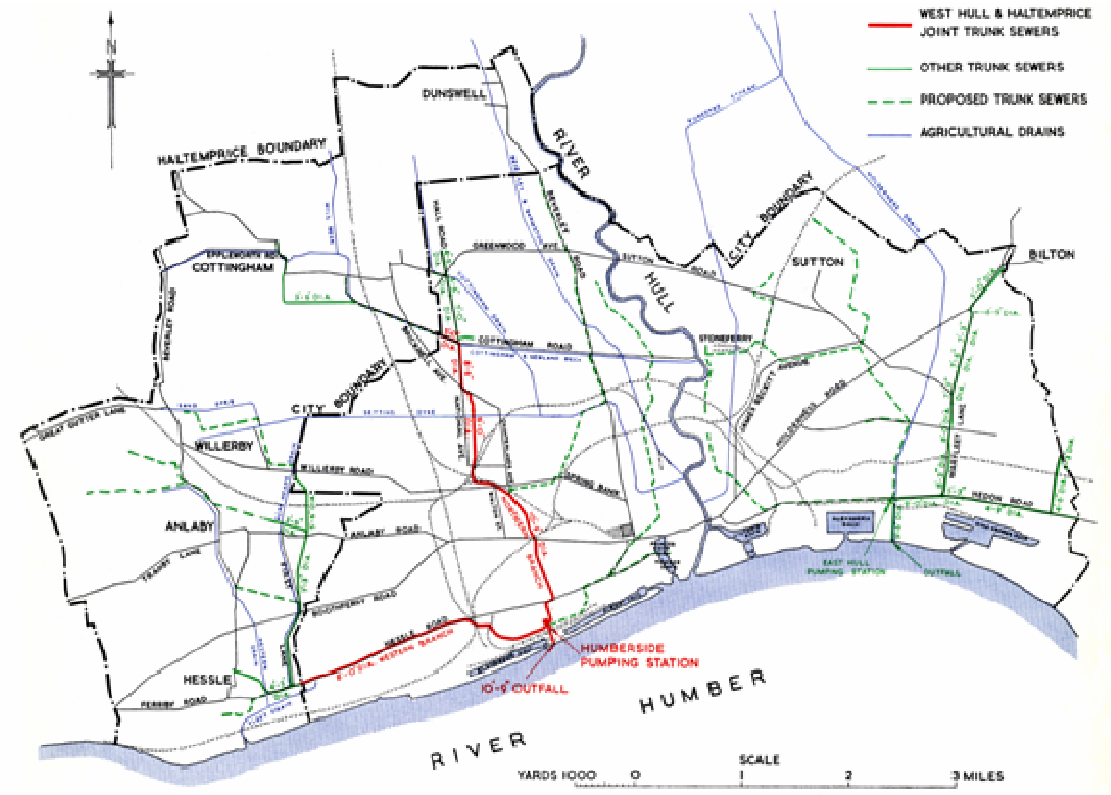

Figure 6.1 Actual and planned sewer network for Hull and Haltemprice, 1957.

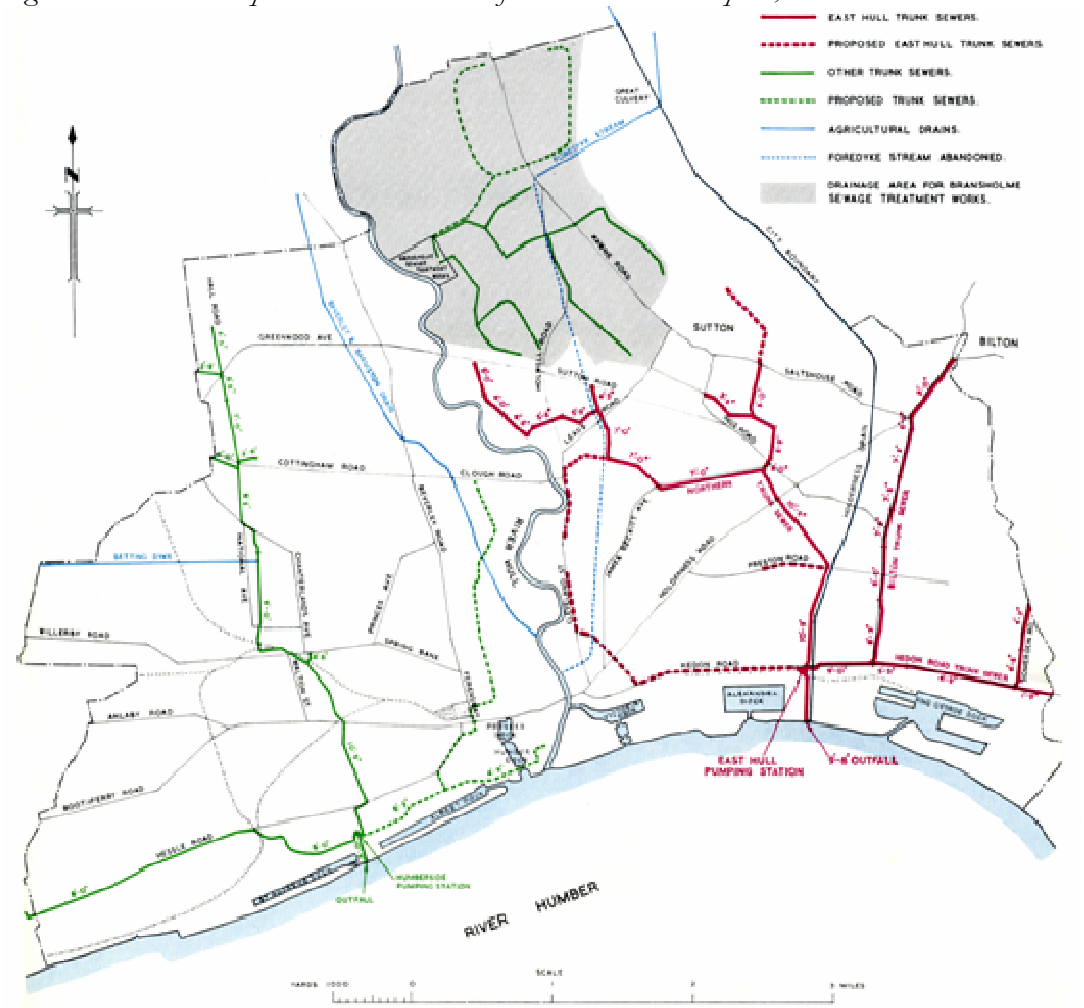

Figure 6.2 Actual and planned sewer network for Hull, 1972.

6.1.2.3 West Hull

In West Hull, a large pumping Station was built in 1957 to pump raw sewage during dry weather and storm water flows during wet weather directly into the River Humber from the city. The original station incorporated 8 storm pumps and 4 dry weather pumps. These gave a combined pumping capacity of 32 m^3s^{-1}. To place this capacity in context, flood flows in the River Hull approach 50 m^3s^{-1}. To transfer water and sewage to the new pumping station, a network of major trunk sewers was constructed during the late 1950's and 1960's. These were important, as they re-organised the drainage areas, adding sewage and surface water drainage from the outlying western areas of Cottingham, Willerby, Anlaby and Hessle to Hull's catchment area. This included the development of a major (3.3m diameter) sewer running North to South (the Northern Branch, Figure 6.1) across Spring Bank, parallel to National Avenue and connecting with the Cottingham and Newland Beck at Cottingham Road. To the west, a major sewer (the Western Branch (Figure 6.1) linked Hessle, Willerby and Anlaby to the new pumping station.

6.1.2.4. Summary of 1945-1973

As a result of these trunk sewers, which were generally large concrete pipes internally lined with engineering bricks, Hull can be considered to have a modern drainage system. Because of the low lying flat nature of Hull, sewer gradients are low, between 1:1000 - 1:1500 and subsequently velocities low. In order to transport large volumes of water the sewers have large diameters. E.g. Bilton sewer diameter 2.7m, Northern sewers diameter 3.3m, Drypool sewer diameter 1.5m, Western sewer diameter 2.4m, Northern diameter 3.3m, Bankside diameter 2.5m. Hull has some of the largest and newest sewers in YW region.

Because of the then new pumping stations and linked sewer systems, many of the open water courses in and around Hull were either culverted or filled in altogether generally in the name of child safety. During their operation, the pumping stations were some of the largest in the UK. Both East and West Hull stations continued to operate with their full potential until the construction of Humbercare in 2000.

6.1.2.5 Bransholme Pumping Station and Catchments

The Bransholme development began in the mid 1950's on very low lying land. The sewerage infrastructure unlike the rest of Hull was split into separate foul and surface water sewers. Both sewer systems were taken to the Bransholme sewerage works where the foul was treated and the run off either stored in a lagoon or pumped directly into the River Hull. Surface water was mixed with the treated sewage. The station was constructed in the 1950s.

Flows enter the surface water pumping station in a wet well. There are no penstocks which could control the flows into the station. Water is then pumped into a higher level channel. Dependent on tide conditions in the River Hull the flows will either gravitate to the river or potential exists for it to flow into an attenuation lagoon until the tide levels drop. There are five pumps installed in the pumping station – 4 diesel pumps and 1 electric pump. The electric pump has a capacity of 0.68 m^3s^{-1} per second, 1 diesel has a capacity of 1.2 m^3s^{-1} per second and the remaining three have 1.8 m^3s^{-1} per second capacity each. The pumps operate in sequence dependent upon flow in the wet well. Only three pumps can run at any one point in time due to restrictions in the outlet pipe work and the configuration of the pumps inside the wet well which means that the capacity of the station is 5.4 m^3s^{-1} per second.

Planning permission exists for an additional 2000 houses discharging into this station, surface water only.

6.1.3 1973 to 2000

The administration of water law in Hull remained local under the control of Hull Corporation until the Water Act 1973, which created ten regional water authorities whose areas were defined by river basins, Yorkshire Water (YW) is the regional authority responsible for Hull and its catchments. Privatisation of the water authorities' water supply and sewerage functions came with the Water Act 1989 and with it transfer of the river functions to a newly created National Rivers Authority (NRA). The NRA was later to be subsumed within the Environment Agency (Environment Act 1995).

To clarify the roles and responsibilities of Yorkshire Water, the law relating to water companies in England and Wales is contained principally in the Water Industry Acts 1991 and 1999 and the Water Act 2003. Also relevant are the Water Resources Act 1991 as amended and other national and European environmental legislation, particularly the Water Framework Directive 2000/60/EC, now being implemented. Under this legislation Yorkshire Water have broadly-framed statutory duties to provide an effective system of public sewers, to maintain sewers so as to ensure effectual drainage, and to make provision for emptying of the contents of those sewers.

The Director General of Water Services is the economic regulator of water and sewerage services in England and Wales and the head of the Office of Water Services (Ofwat), and is accountable directly to Parliament and Welsh Assembly. Ofwat has a statutory duty to ensure that each company carries out its functions properly and must use its powers in ways best calculated to ensure that each company, operating economically and efficiently, is able to finance its functions. Subject to these duties, Ofwat has a duty to protect customers' interests in relation to price and quality of service. Ofwat also has powers to enforce the companies' duties.

Figure 6.3 Present day drainage system (source Yorkshire Water).

6.1.4 2000 to 2005: Humbercare

In 2000 and as a result of an EU directive YW developed a scheme to treat the sewerage generated in Hull's combined drainage system (excluding surface water from Bransholme) called "Humbercare".

Briefly Humbercare comprises a transfer tunnel, 3.6m in diameter and 10.5 kilometres long running 30 plus metres below ground level parallel to the Estuary (Figure 6.3). The tunnel connects West and East Hull sewers to a new sewerage works and outfall sited at Saltend. The system carries sewerage by gravity from the entire east and west region trunk sewers during dry weather – up to 6 m^3s^{-1} per second are fully treated and up to 12 m^3s^{-1} are partially treated. When the flow exceeds these levels the water bypasses the treatment works and discharges through filters directly into the River Humber. East Hull pumping station continues to pump the Holderness drain at high tides. East Hull and West Hull pumping stations are still operational (West Hull at reduced capacity) and act as 'emergency pumps' when the new Humbercare tunnel is full. In effect, Humbercare drains all water from West and East Hull to Saltend, but when at capacity, East and West Hull pumping stations kick in to remove excess water. The new Yorkshire water facility at Saltend has 4 dry weather flow pumps and 12 storm pumps providing a total of 22 m^3s^{-1} of pumping capacity. As a result, today, the pumping capacity of the system remains broadly equivalent to the pre-Humbercare configuration (around 58 m^3s^{-1}), with the substantial addition of storage capacity in the tunnel. The pumping capacity was reallocated by a reduction in capacity of the West Hull and East Hull stations compensated for with increased capacity at Saltend.

Importantly, the completion of this major scheme put an end to raw sewage being pumped into the Humber Estuary.

The IRB are concerned that the main Humbercare sewer is fed at West Hull by three sewers of diameter 2.4, 3.3 and 2.5m, and at East Hull by three sewers of diameter 2.7, 3.3.and 1.5m, yet has a diameter of only 3.6m. The gradient of Humbercare is c.1 in 1535. (*Source Yorkshire Water)*

6.1.5 2005 to 2007

The development of Humbercare afforded Yorkshire water with an opportunity to re-visit and re-model the existing pumping infrastructure, which at the time included West and East Hull pumping stations. The most sophisticated hydraulic modelling commissioned at the time (late 1990's: the 'Hydroworks' model by Wallingford Software) suggested that the vast new storage capacity in the tunnel (103, 963 m^3) and the 22 m^3s^{-1} pumping capacity at the new treatment works would provide protection from a 1 in 30 year rainfall event. Therefore, the West Hull pumping station was no longer deemed necessary for general operation and was retained for emergency use only.

In 2005, modelling using new generation 'Infoworks' software (again provided by Wallingford Software) provided much more accurate predictions of storm flows and in particular the effects of long duration multi-peak storms and the contribution of slow response runoff on the system. This meant that the new numerical model of sewer flow could account for the catchment already being saturated due to previous storms, as well as model the impact of longer lower intensity storms - with more than one peak. As a result, in 2005, new investment was made to refurbish two extra storm pumps at West Hull and generate a pumping capacity to a maximum of around 16-20 m^3s^{-1}.

The IRB investigations have revealed a wealth of local design knowledge that to our knowledge was not accessed in the original design process. Reliance on numerical modelling is only as good as the information and data entered. It is a recommendation that project management and design co-ordination place a high importance on the gathering of local knowledge and expertise both cross agency and from retirees, and that design proposals receive independent scrutiny. This is especially important when reviewing pre 1973 designs such as Bransholme pumping station which was designed and built pre Yorkshire Water who inherited the design.

6.1.6 Pumping and sewer capacity

Due to re-configurations of the pumps over the last 100 years below we have provided a summary of the pumping capacity of the Hull catchment.

Station/Sewer location	Outflow capacity m^3s^{-1}	Pre Humbercare 2000 – 2005 m^3s^{-1}	Humbercare 2000 – 2005 m^3s^{-1}	2005 to present m^3s^{-1}	Potential pumps restored or upgraded
Saltend	22	N/A	22	22	22#
East Hull	24	26	15##	15	19**
West Hull	33	32	8	20***	32
Bransholme	7.2	5.4	5.4	5.4	7.2*
Total (m^3s^{-1})	86.2	63.4	50.4	62.4	80.2

Table 6.1 Pumping Capacities of the Hull Catchment (Source Yorkshire Water Independent Publications)

*Modifications required to pumping station and infrastructure.
**Major civil works to the structure of the transfer tunnel would be needed to raise this figure to the pre Humbercare figure of 26 m^3s^{-1}.
***Included a 4 m^3s^{-1} capacity pump which worked intermittently.
#Assumption only requires investigation.
##Capacity includes the pumping of Holderness drain.

The IRB is concerned that there is a lack of actual flow data from YW's pumping operations or of sewer flow rates. With the exception of Saltend, there is little data from the event about actual flow rates and volumes pumped. There is depth data, but not on discharge volumes. Such data is vital for validating numerical models of the system, and we are very surprised that this does not exist.

6.2. What happened - Yorkshire Water's account of 25th June.

6.2.1 Summary

Surface water flooding which affected Hull during June 2007 was the result of exceptional rainfall events on 15th and 25th June. The sewerage and pumping infrastructure in Hull was filled to capacity and over-whelmed by the severity of the storms and the concentration of the rainfall. No drinking water supply was interrupted and there were no blockages in the sewer system which ran full to capacity.

6.2.2 Chronology of events

On the 12th June, the Met Office warned that unseasonable rainfall may lead to flooding in Yorkshire and the Midlands.

This warning came dramatically true on 15th June when exceptionally heavy and prolonged rainfall impacted the region leading to widespread flooding. Yorkshire Water's own Core Incident Management Team (CIMT) was established at the company's Regional Operational Control Centre (ROCC) in Bradford to co-ordinate the company's operational and customer service response.

On 25th June, over a month's rain fell in 24 hours swamping the sewerage infrastructure in Hull The company battled hard to maintain treatment and pumping at its Saltend Waste Water Treatment Works, despite rising flood waters and the risk of power cuts disabling the Works. As the heavy downpours continued the sewer network was overwhelmed and, as the water had nowhere to escape or discharge to, there was extensive surface water flooding in a number of low lying areas of the city. In the East Riding, the high levels of the Burstwick Drain prevented emergency discharge of flood waters from the sewerage system. In the West, the Setting Dyke and the Cottingham Drain flowed into the sewerage system.

At Saltend, the Humbercare interceptor tunnel began rising during the early hours of 25th June and reached its full capacity later that morning. The trend of levels within the tunnel and inlet wells at East Hull and West Hull can be seen on the graph provided by YW. The Saltend works operated well throughout, despite having 600mm of flood water on parts of the site. The works receives National grid power from a dual source, but to a single substation. Protecting this substation from shutting down due to flooding was a major concern, in the event temporary flood barriers were erected by Yorkshire Electricity as flood waters reached a critical level.

The IRB ask that Yorkshire Water assess the resilience of the station and report back with a new proposal for standby generation.

At west Hull four storm pumps refurbished in 2005 pump 4 m^3s^{-1} each and worked well throughout the storms on both the 15th June and the 25th June. A fifth storm pump worked intermittently.

The inlet penstocks to West Hull Pumping Station were opened at approximately 0700 hours on the 25th June and the station was run until late on Wednesday afternoon when the levels in the tunnel had reduced and hence the flows arriving at West Hull SPS. Unfortunately YW do not have any records for when the flows were diverted on 15th June nor the time at which the pumping station ceased operation.

The station was manned throughout the storms and pen-stocks into the station and to the outfall were operated to prevent over whelming of the station. At this stage, we are not aware of any problems with the operation of the pen-stocks. This action does however suggest that had more pumping capacity been available the station could have been utilised.

At East Hull during the week commencing 25th June the pumping station was bought into operation at exactly the same time as West Hull SPS at 0700 hours on 25th June. Flows continued to be diverted into the tunnel until the early hours of 28th June. However, the station was still manned into the second week due to the very high levels in the Holderness Drain. Once the station stopped pumping flow from Humbercare, Yorkshire Water were able to divert more flows than normal from the Holderness Drain. YW normally only pump the Holderness Drain at high tide. The operation YW carried out during the floods was to constantly pump the Holderness Drain during all tide conditions. This had an important effect on the draining down of this major land drain

At Bransholme, the pumping station was operating at capacity throughout the 25th of June. The station was eventually flooded itself on the morning of 26th June as storm waters rose 6m up the wet wall to submerge and eventually seize the pump bearings.

The failure of the station resulted in a delay in draining flood waters from the area.

6.3 Design criteria past and present

It is not clear what size event the system was previously designed for during the 1950's to 1970's. However, reference is made to developing a system to deal with a growing population of up to 250 000.

For present day sewer design, the national standard for new sewers is a 1:30 level of protection for both internal and external flooding. New sewers for adoption by YW must be built to an industry standard document "Sewer for adoption, 6th edition" published by the Water Research Centre.

The definition of a 1 in 30 level - or a 1 in 30 year event is not straight forward, as rainfall calculation is a function of depth of rain over the time in which it falls. Based on the Centre for Ecology and Hydrology's "Flood Estimation Handbook", the following times /depths equate to a 1 in 30 year event are shown in Table 6.2. We have also plotted similar data from Table 1.1 for comparison. If these data are compared to the rainfall recorded on the 15th and 25th June 2007, as shown in Figure 1.2, it is clear that rainfall on both these days exceeded the level of a 1 in 30 year event.

Duration	**Rainfall total for 1 in 30 year event (mm)**	**Highest recorded rainfall rates in the UK (mm)**	**Data from Hull, June 2007 (mm)**
30min	25	80	
1hr	30	92	
2hrs	36	193	
6hrs	49		
12hrs	59		70 (15th June)
24hrs	70	279	110 (25th June)
48hrs	82		

Table 6.2 Rainfall totals and intensities for a 1 in 30 year event compared to highest totals recorded in the UK..

6.4 Yorkshire Water's recommendations after the 25th June floods

In response to a series of detailed questions raised by the IRB, Yorkshire water produced a ten page document, outlining some of the details we have already mentioned. Concluding their statement, they issued a refreshing set of statements and goals.

"*It is important not to draw conclusions too early until a full technical review and appraisal has been carried out by the responsible agencies.*

In our view, a key first step should be a major hydraulic study to model flows in the city as a whole and to better understand the impact on systems of climate change which may result in an increased frequency of major rainfall events and rising sea and river levels. This may then lead to recommendations to upgrade the system, or re-model the existing configuration."

The IRB consider that a major hydraulic study is vital, and we congratulate YW for this initiative. We hope they carry out these studies and importantly include projections of climate change in accordance with the latest Ofwat recommendations.

"This would necessarily involve the city making choices on what level of risk and protection is required, taking into account the likely impact on customers' bills of any major new investment in the sewerage and pumping network. It should be recognised that even the best infrastructure in the world would most likely to over-topped and over-whelmed by 1 in 150 year rainfall events."

The IRB agree that it is difficult to decide what level of protection is appropriate. However given the occurrence of two greater than 1 in 30 events within ten days in June 2007, we seriously question whether a 1 in 30 level of protection is adequate. We believe that Hull is in a unique position and its reliance on pumped drainage mean that a greater level of protection AND contingency (e.g. backup pumping) should be incorporated.

"*At Bransholme, we have committed to immediate short-term investment to protect the station in order to reassure residents and are exploring longer term solutions to modernise the 50 year old station in discussion with the developers and the City Council in light of proposed new housing development. Any decision to increase pumping capacity at the station must be considered carefully however in view of its likely impact on the River Hull and the existing attenuation lagoon.*"

The IRB suggest that measures to remediate the problem at Bransholme should consider a more integrated solution, including opening up watercourses and linking these into the Holderness Drain.

The IRB is awaiting reports commissioned in 2002 on the condition and development proposals for the station. The IRB also awaits details and confirmation of design data relative to the sizing and development of the Bransholme station. We have asked YW to re-visit the design using the latest modelling software and to report back with the design resilience and to confirm a 1:30 year design status.

"*Further major investment could also increase pumping capacity by around 12 m^3s^{-1} at West Hull and 4 m^3s^{-1} at East Hull by replacing or refurbishing redundant pumps. It is impossible to say without further modelling however whether this would have a significant overall impact on the level of protection provided given the overall capacity of the drainage and sewer network."*

The IRB believe the probability of benefit from increased pumping capacity is high given that it was necessary to control the inlet flow at West Hull. We feel this is indicative of lack of pumping capacity being a

factor. This is a decision that must be informed by numerical modelling backed up by real data.

"*Yorkshire Water has over 1,100 km of sewers in Hull and a technical study could be undertaken to identify 'pinch' points. This may highlight further upgrades to the system."*

This technical study must include comprehensive analysis of existing flow data. Where data does not exist, new data must be collected.

"We also believe that there should be better co-ordination of the emergency response for customers with a single point of contact for flood emergencies."

We agree wholeheartedly with this recommendation.

7. Overall findings

The floods on the 25th June were caused by Hull's pumped drainage and sewerage system being overwhelmed by the volume of rainwater. This led to backing up of water along the sewer and drainage network leading to widespread flooding across Hull. Despite the devastation there are many positives to take from the floods. **Given the magnitude of the storm (greater than 1 in 150 years) we feel it is very encouraging that key pieces of important civil infrastructure did not fail**. Hospitals were open, Electricity supplies were (largely) uninterrupted, and drinking water supplies also functioned throughout. Telephone and other utilities also worked throughout the storm and days after. Sadly, there was one fatality, but it is to the great credit of Humberside Fire and Rescue as well as Hull City Council operatives and other Agencies that there were no other major casualties. As mentioned in the introduction, this interim report focuses on the physical nature and causes of the flooding. In the second part of our review, we shall focus more on the social and human impacts.

The IRB have identified key factors that may have exacerbated the flooding. As Hull's drainage system is entirely pumped, Hull is reliant upon these pumps working and being designed to the correct capacity. **We have significant concerns as to whether the pumping system, that was re-evaluated for the Humbercare project (post 2000), is correctly designed to cover a 1 in 30 year storm event**. In 2005, Yorkshire Water re-modelled the Hull catchment using new software and subsequently re-instated de-commissioned pumps at West Hull pumping station. We welcome Yorkshire Water taking a pro-active stance by acting immediately upon the results of the new modelling study. **However, this indicates that Humbercare, or parts of the Humbercare system, may not have been designed to afford protection from a 1 in 30 year storm prior to 2005.** The IRB have no information on the new modelling study, what weaknesses may have been revealed by it, nor details of the levels of protection provided pre 2005. Furthermore, Yorkshire Water appear to have a lack of monitoring data on sewer and pump discharges that make it very hard to assess how well the sewer and pump system was operating. This is a matter of concern.

At West Hull pumping station there are additional de-commissioned pumps and the civil infrastructure exists to re-instate further pumping capacity there. The effectiveness of re-commissioning these additional pumps could be diminished if the capacity of the existing sewer system to deliver water to the pumps is not sufficient. However, we believe that evidence of valves (pen stocks) being used to restrict water entering the pumps on the 25th June indicates that there was more water than could be pumped. **Importantly, the availability of additional pumping would also provide backup, or contingency, should any of the existing pumps fail**. All of the above needs to be investigated thoroughly by Yorkshire Water, in co-operation with Hull City Council and the Environment Agency. Later, we suggest possible alternatives to enhance the drainage capacity, and we urge the above agencies to examine these and give them due consideration.

Bransholme and Kingswood have a separate drainage system and pumping station that failed at 6am on the 26th June due to becoming flooded itself. We have found no documentary evidence of what magnitude storm event the Bransholme pumping station is designed to accommodate. **We feel that it is unacceptable that there were no contingency plans for the failure of Bransholme pumping station nor protection from flood water at this key piece of infrastructure.** We urge Yorkshire Water, the Environment Agency and Hull City Council to expand contingency and investigate alternatives urgently.

A major concern of the IRB are the design criteria used to design the drainage system. These are based on industry guidelines of protecting up to the level of a 1 in 30 year storm. We agree that there may be little point in building a 'gold plated' system to protect against a huge storm that may never happen, but Hull's low lying position increases its vulnerability. Therefore, we recommend that for this reason **Hull should have additional levels of protection above and beyond a 1 in 30 year storm event.**

Furthermore, **we have no evidence that the present design includes protection from changes in weather due to climate change.** In June 2007 Hull has experienced two events of magnitude greater than 1 in 30 years, and predictions of the effects of climate change suggest that extreme events (including rainfall) will become more common in the future. The Environment Agency design flood defences to withstand a 1 in 100 year event, then add 20% for the possible effects of climate change. **Again, we argue that for this reason Hull should have additional levels of protection above and beyond the present day calculated 1 in 30 year storm event**.

At a national level, the level of protection for drainage systems is set at 1 in 30 years by an industry standard. There is no indication of whether this is regularly updated to incorporate new large storm events that will increase the size of a calculated 1 in 30 year storm, nor whether present day drainage systems are regularly re-checked and re-evaluated to ensure they meet new levels. Furthermore, there appears to be no accommodation for climate change in these design criteria. **Nationally, we suggest that for urban drainage the level of 1 in 30 years should be reviewed as a minimum, and that some additional capacity should be factored in for possible climate change.**

The events allow the IRB to consider how HFRS could be better informed and supported during exceptional events. The public and all Agencies may benefit from a clearer understanding of the responsibilities of HFRS during a flood event. The combined emergency command procedures should ensure that **agreed strategic locations** are protected to help HFRS prioritise its workload. Contingencies for emergency communication breakdown or exceptional demand may also be considered. HFRS received support in call handling, staff and equipment from other regional Fire and Rescue Services. If not already in place a more formal system of support between regional Fire and Rescue Services may help provide the immediate resources necessary to handle enquiries and prioritise efforts. **On an 'expect the unexpected basis' the IRB encourage the relevant agencies to have available the standby pumping capacity to meet a 1 in 30 rainfall event alongside tidal flood risk capacity**. Furthermore, the IRB raise the question of who should be responsible for pumping floodwaters from property which is not in the statutory remit of HFRS. At present it is unclear who has responsibility to pump flood waters.

Flooding was most extensive in West Hull as it receives rainwater runoff from the Haltemprice area of the East Riding of Yorkshire. This area is topographically higher than Hull and feeds directly into Hull's water courses and sewer system. Effectively, West Hull acts as a sump. This is also the area which is furthest from the outfall of the Humbercare system and the West Hull pumping station only functions when the Humbercare transfer tunnel is full. This issue needs to be addressed urgently. We feel there are several options open to alleviate this, that we shall discuss in the recommendations section.

Generally, Silver Command coped well with the immediate emergency, however there are important lessons to be learned. Surprisingly there was a lack of local knowledge of Hull City regions from Silver Command hierarchy as well as a need for a list of key points of civil infrastructure. Silver Command is reactive and (for example) will only be alerted once

threats to key items of infrastructure have occurred instead of anticipating dangers. Communication to the public from Silver Command needs to be better managed, formalised and more frequent. Local media are vital for disseminating information and we suggest that direct and possibly formal links are made for future situations. At present it seems uncertain as to whether Gold command would have been beneficial. This adds another layer of bureaucracy but also introduces greater authority. We ask those involved in Silver Command to evaluate whether it could have operated more effectively.

The overall management of Hull's drainage system is confusing. It involves a multi agency inter-relationship and responsibility for gullies, sewers and watercourses. For example, rain may fall in East Riding (e.g. Cottingham), fall on a roof of a privately owned house, from there down to a soakaway. If saturated this water may then flow across the land entering an open drain or watercourse (e.g. Cottingham Drain). From there it flows south towards Hull, where the watercourse becomes a culverted drain, joining water from private and local authority gullies and feeds into a sewer. This water may then travel through the Humbercare transfer tunnel to Saltend in East Hull, or in storm conditions may be pumped into the Humber at West Hull pumping station. Through this journey, the water is the responsibility of the private home owner, then the Environment Agency, then Hull City Council and finally Yorkshire Water. In this instance, there are four bodies or agencies that can control and have responsibility for the passage of this water. This illustrates the problem of coming up with an integrated management and design solution.

In short no single agency accepts responsibility for any elements outside their own terms of reference nor have they historically allowed others to influence their own obligations. This is a recurring theme - one of inadequate consultation, co-operation and unity between the agencies. These practices must end.
During the review process all of these agencies have started to work together on mapping the existing drainage network and areas of responsibility. We welcome this development and their commitments to continue this co-operation.

In Hull, and nationally as we understand, there is no system for warning for rainfall related flood events. There is an urgent need for predictive modelling to forecast the areas at risk from severe rainfall events. **There is presently no rainfall flash flood warning system. This must be rectified.**

8. Recommendations:

8.1 National recommendations:

To the best of the IRB's knowledge, **there is no system nor guidelines, nationally or locally for warning of the dangers from pluvial (rain based) flooding.** The Environment Agency has significant expertise and infrastructure to warn from tidal and fluvial (river) based flooding but not for pluvial events. We appreciate pluvial flooding from intense rain storms may be harder to predict, but **given the widespread damage caused across the UK by pluvial events in June and July 2007, we feel it is a matter of great urgency that new warning systems and procedures are investigated**. We recommend the EA explore expanding the floodline system to cover all types of floods.

The flooding in Hull has revealed the difficulties of having multiple agencies responsible for different areas of the drainage system. It is apparent throughout this report that this created confusion during the emergency and has led to deficiencies in the planning and day to day management of drainage. We would be surprised if some of these multi-agency organisational issues were not found elsewhere in England and Wales. **We feel it is vital that the Environment Agency, Local Authority and Water Company closely co-operate on operation and design**.

It appears that there are no statutory levels for protection from rainfall flooding. Design criteria are based on an industry standard of protection from a 1 in 30 year event. **We welcome Ofwat's current re-appraisal** ("Out of sight out of mind" report; Ofwat) **of the design standards and the appropriateness of best practice and behove them to consider the impacts of climate change**.

8.2. Local recommendations

We feel that Hull is in a unique situation due to its vulnerability to flooding. We have four suggestions that could reduce the vulnerability as well as increase the resilience to rainfall flooding.

Firstly intercepting and limiting the passage of water into the drainage system. This may include diverting waters from the western side of the catchment utilising existing water courses. For example, waters from Cottingham and Cottingham Drain could be routed north of Orchard Park and east into the Beverley and Barmston Drain. This would then flow south towards Hull City Centre using the existing outlet into the River Hull adjacent to Scott Street Bridge. This may require additional pumping. Another alternative is to pump stormwater from Hessle into the Humber via the Fleet Drain or the presently redundant New Clough outfall. This could remove significant volumes of water from the West Hull drainage system.
To slow down the addition of water to the drainage system land may be bunded to create temporary reservoirs. This could utilise open land including playing fields and car parks and redundant water courses.

Secondly, increase the pumping capacity of Hull. It is our recommendation that following thorough investigation the de-commissioned pumping capacity at East and West Hull pumping stations should be re-instated. Even if pumping capacity exceeds the delivery rates of the sewers, this will add contingency and therefore resilience to the system. As previously stated much of the infrastructure already exists. Additionally, we recommend portable pumping should be more readily available. This could be used to back up any pumping failures or to enhance existing pumping capacity in times of need. We recommend that these facilities should be kept in the locale of Hull, to prevent delays in deployment (as happened on the 25th June). This is a measure that could be implemented immediately. Finally, power supply to all these pumping facilities must be protected.

Thirdly, the management of water drainage in Hull City. We recommend that an independent Drainage Board for Hull is set up, to both facilitate and enforce communication between the agencies. This Board could be responsible for developing a joint, co-ordinated and coherent strategy for water management within the catchment of Hull.

Fourthly, it is imperative that all agencies agree a list of key strategic locations for protection in flooding emergencies.

9. Acknowledgements

We are very grateful for all contributions to this report. Much of the data used here was provided at short notice and we are particularly grateful for the help of: James Trowsdale, One Hull; Andrew Taylor and Robert Salmon, Yorkshire Water; Jan Davies and Tony Atkin, Environment Agency; Trish Dalby, Hull Streetscene; Maz Khuri, HFRS; Jack Greensides