



YorkshireWater

YORKSHIRE WATER SERVICES

Humbercare Sewerage Network Analysis

1 Summary

1.1 Introduction

- 1.1.1 Following flooding in Hull in June 2007 we have been asked by Ofwat to investigate, model and explain the performance of our drainage assets in Hull.
- 1.1.2 This report focuses on the performance of the 'Humbercare' system (East and West Hull Pumping Stations, Saltend Waste Water Treatment Works and the connecting transfer tunnel) and its impact on the public sewerage network connected to it. It also comments on the operation of Bransholme Surface Water Pumping Station.
- 1.1.3 For Humbercare, modelling work was undertaken by MWH, an independent engineering consultancy with expertise in sewer network modelling.
- 1.1.4 The performance of Yorkshire Water's Humbercare assets has been modelled under a range of worst case storm conditions for 1 in 10, 1 in 20 and 1 in 30 year return periods. (1 in 30 is the accepted industry standard level of flood protection for new sewerage systems).
- 1.1.5 The model simulates the performance of the assets existing in June 2007 and, following the company's ongoing asset improvements, expected to be complete in Autumn 2009. The model has also been used to make comparisons with pre-Humbercare levels.
- 1.1.6 The model has some limitations however and is not suitable for predicting individual property flooding, or for 'levels of service' as defined by Ofwat's 'DG5' measure, which records properties and areas at risk of internal or external flooding.

1.2 Performance of our drainage assets in Hull in June 2007

- 1.2.1 The model indicates that in June 2007 92.5% of the modelled network had a level of flood protection greater than 1 in 30. This is 2.1 percentage points lower than the pre-Humbercare situation of 94.6%
- 1.2.2 For 1 in 20, the level of protection is 1.7 percentage points lower than pre-Humbercare, with no change for 1 in 10.

1.3 Expected performance of our drainage assets in Hull by Autumn 2009

- 1.3.1 Modelling of our planned asset improvements indicates that by Autumn 2009, 95.4% of the modelled network will have a level of flood protection greater than 1 in 30. This

is 0.8 percentage points better than the pre-Humbercare situation.

- 1.3.2 For 1 in 20, the level of protection is 0.2 percentage points better than pre-Humbercare and marginally better for 1 in 10.

1.4 Future levels of protection – what more needs to be done

- 1.4.1 We have also modelled the performance of our drainage assets assuming unlimited pumping capacity (called 'free discharge').
- 1.4.2 The results indicate a level of protection equivalent to the one expected from our current investment (an improvement on pre-Humbercare levels for all storm events). This means that our investment will effectively maximise the contribution that pumping can make to flood protection in Hull.
- 1.4.3 Even with unlimited pumping capacity (a hypothetical situation) around 5% of the modelled network is still predicted to flood for a 1 in 30 year storm, which indicates that further protection is dependent on resolving long standing capacity constraints within the network.
- 1.4.4 This reinforces the need for an integrated approach to urban drainage which will require all responsible agencies to work together to manage storm water in and around the city.

1.5 Our operational response on June 25th 2007

- 1.5.1 We have undertaken a review of our operational response and we have concluded that it was in line with our standard emergency procedures.

1.6 Our Bransholme SWPS response on June 25th 2007

- 1.6.1 On the June 25th 2007, our storm water pumping station at Bransholme operated in line with normal procedure. Early on June 26th, the pumping station itself was inundated with flood water. This resulted in the failure of critical equipment at which point the station failed. Temporary pumping was sourced as quickly as possible, with pumping operations fully restored within 26 hours.
- 1.6.2 We are now in the final stages of installing 100% standby capability at Bransholme by the end of July 2008. Discussions are continuing with key stakeholders regarding future development needs.

2 Background information

2.1 In March 2008, Yorkshire Water agreed with Ofwat to:

- Fully investigate, model and explain the performance of its drainage assets in Hull existing in June 2007, and with the asset improvements it has already announced, under a range of storm conditions (including long duration events)
- Set out what conclusions can reasonably be made regarding the level of service delivered in June 2007
- Demonstrate and explain the improved service to be delivered once the planned asset improvements it has already announced, have been commissioned
- Subject this work to independent audit by its independent reporter approved by Ofwat
- Provide a report summarising these actions and the conclusions drawn to be published¹

2.2 Yorkshire Water has produced this report in response to the agreed actions set out in paragraph 2.1 above. The report is based on information collected internally from our review of the events on June 25th 2007 and is also informed by modelling information that we commissioned MWH, an independent engineering consultancy with expertise in sewer network modelling, to produce.

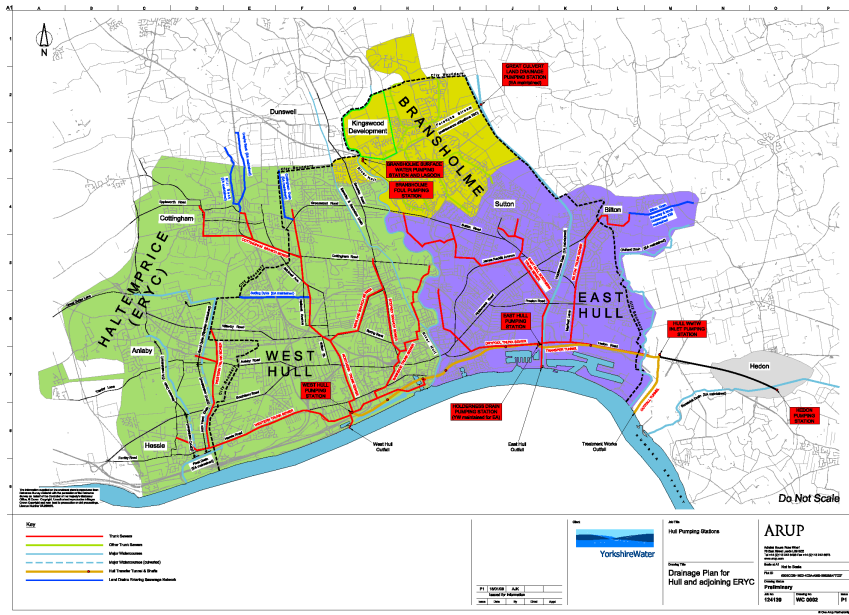
2.3 The report focuses on the performance of the 'Humbercare' system (East and West Hull Pumping Stations, Saltend Waste Water Treatment Works and the connecting transfer tunnel) and its impact on the public sewerage network connected to it.

2.4 In this document references to "Hull" relate to the City of Kingston Upon Hull and the adjoining areas of the East Riding of Yorkshire which are the areas served operationally by the Humbercare system.

2.5 Bransholme is not part of the Humbercare system. However, a section on Bransholme Surface Water Pumping Station is included in this report.

2.6 For illustrative purposes, the map below highlights the areas served by both Humbercare and Bransholme.

¹ Ofwat Press Release dated March 2008



3 Hull and the Humbercare Catchment

3.1 Surface Water Management

3.1.1 Yorkshire Water is responsible for the public sewers as identified on statutory records.² It is not responsible for the maintenance of open watercourses, ditches and dykes, culverted watercourses, private drains and sewers, highway gullies and their associated pipework. However Yorkshire Water is required to manage these flows on entering the public sewerage system.

3.1.2 68%³ of Hull is low lying and below high tide level and is protected by flooding from the estuary by extensive flood defences. Higher ground exists on either side of the catchment, creating what is in effect a wide bowl.

3.1.3 In most UK drainage systems, rivers and watercourses relieve the pressure on the drainage system, allowing water to escape. Unusually, in Hull, five major watercourses are actually piped into the sewers.

The surface and ground water discharges from the higher ground of the East Riding and the Wolds flow through the city of Hull, carried by large land drains including the Setting Dyke, Mill Beck, Creyke Beck, Cottingham Drain, Bilton Drain and the Holderness Drain. These all flow into the sewerage network. The Environment Agency has the responsibility for maintenance of these drains with the exception of the Bilton Drain which an Internal Drainage Board has responsibility for.

3.1.4 The western part of Hull is affected by the chalk aquifer and during periods of prolonged wet weather the water table can rise. This can often lead to ground becoming more saturated affecting its ability to drain. This may also lead to an increase in surface water run off during wet weather.

² Identified on public sewer records under section 199 of the Water Industry Act

³ MWH - LIDAR data analysis

3.2 The Humbercare System

- 3.2.1 The Humbercare scheme was constructed in the late 1990s to meet the requirements of the EC Urban Waste Water Treatment Directive. The scheme was not driven by the need to change the drainage system's capacity but by the need to improve the quality of discharges from it with regards to the discharge of raw, untreated sewage into the Humber.

The scheme involved the construction of a new tunnel to transfer flows to Saltend, (the location of the Waste Water Treatment Works). Although the original scheme was a water quality scheme, maintaining the level of flood protection was part of the design process.

- 3.2.2 A feasibility study was undertaken by Yorkshire Water and others during the 1990s to determine the optimum scheme. Hydraulic modelling was undertaken using the 'Wallrus' software initially and thereafter the 'Hydroworks' computer software.

Hydroworks was one of the leading tools at the time for modelling urban drainage systems.

- 3.2.3 The model predicted that the combination of new pumping capacity at Saltend and over 100,000m³ of storage in the transfer tunnel would provide an equivalent level of protection to pre-Humbercare. East and West Hull pumping stations have been retained for emergency use only.

4 June 25th Event and Our Response

4.1 Extreme Weather Conditions

4.1.1 Summer rainfall can be heavy, but is usually relatively short in duration. The series of extreme storms which impacted Yorkshire in June 2007 were particularly unusual due to the amount of rainfall which fell and the length of time it lasted.

4.1.2 In Hull, 105mm of rain was recorded at Saltend on June 25th. This is around two month's average rain in a single day. This followed a significant rainfall event on June 14th and 15th.

June 2007 was the wettest recorded month in Yorkshire since 1882⁴.

There was a rapid rise in the water table in the Hull Chalk Aquifer in June 2007. On June 25th, the aquifer was at 63% of its normal level, rising to 98% by the end of the month, illustrating the volume of water entering Hull in June.

4.1.3 In their March 2008 report to Ofwat, engineers WRc concluded that: "The combined effect of exceptional rainfall and a saturated ground/high water table will have been the main cause of the flooding. No urban drainage system in the UK will have been able to cope with those conditions."⁵

4.2 Our Response in Yorkshire

4.2.1 Our operational response in Hull should be seen in the context of the company's wider operational response in the region. Throughout the period, we operated Company Incident Management Teams at our regional control centre to manage the event and liaise with Gold and Silver command teams.

4.2.2 Over 30 sewage treatment works and 100 pumping stations were flooded in Yorkshire.

4.2.3 Our initial emergency response secured a return to normal operation of the impacted infrastructure, albeit with temporary equipment.

⁴ EA Report 2007 – Summer Floods

⁵ WRc Report – March 2008

- 4.2.4 We ensured that the drinking water supply in Yorkshire was maintained.
- 4.2.5 Our reservoirs and dams were checked for structural integrity. Yorkshire Water engineers were released to advise the emergency services to shore-up the Ulley Dam, owned and operated by Rotherham Metropolitan District Council, which was the regional priority at the time.

4.3 Our Humbercare Response on June 25th 2007

- 4.3.1 Ahead of the storm events in June all Humbercare pumping stations were available to operate under emergency conditions. The operation of the East and West Hull pumping stations occurs only when and where there is clear risk to life or property pursuant to the Water Resources Act 1991.
- 4.3.2 Levels were monitored at Saltend and in the sewerage network constantly. At 05:36⁶ a level monitor in the sewerage system triggered a telemetry alarm. This together with our operational information led us to implement the Hull Emergency Procedure.
- 4.3.3 The terms of the consents restricting the operation of East and West Hull pumping stations means that we can manually start the pumps, only after there has been liaison with the Environment Agency.
- 4.3.4 By 06:00 our Hull based operational team was in attendance at the pumping stations. The Yorkshire Water Duty Manager, based at the Regional Control Centre in Bradford, was kept constantly informed. At 06:40, the Duty Manager notified the Environment Agency of actions relating to the implementation of the Emergency Procedure and the operation of the pumps commenced.
- 4.3.5 All available pumps operated at Saltend, West and East Hull pumping stations during the storm. Levels at all pumping stations remained elevated until Thursday June 28th, when they returned to normal.
- 4.3.6 Yorkshire Water asked to join the Hull Silver Command Team on June 25th. We were invited to join the group on Wednesday June 27th.
- 4.3.7 Our review of our own processes has demonstrated that our response followed all appropriate normal and emergency procedures. Resources were planned and coordinated to ensure there was no shortage of manpower throughout the events.

⁶ All times quoted in GMT

5 Review and Investment

- 5.1 We have contributed to regional reviews in Hull, Leeds, Rotherham, Doncaster, Barnsley, Sheffield, East Riding of Yorkshire and to national reviews including the Pitt Review and the EFRA Select Committee Review.
- 5.2 Following the flooding in Hull in June 2007, Yorkshire Water commissioned its own report. Ove Arup & Partners (Arup) completed a review of the performance and operation of our pumping stations during the flooding. We have shared this report with other relevant stakeholders.
- 5.3 This report made a number of recommendations including work to improve the reliability, robustness and capacity of East and West Hull pumping stations.
- 5.4. Based on the recommendations of the Arup report, a major £16 million scheme is underway to maintain and then increase pumping capacity at West Hull by the end of June 2008; to increase the inlet capacity at East and West Hull by the end of June 2008 (civils work) and to complete further pumping capacity at West Hull by Autumn 2009. New control systems will be in place by August 2008. Further additional maintenance work at East Hull is planned for 2011. To get maximum benefit from the investment we will need to change the operating regime for these pumping stations and we will continue to liaise with the Environment Agency on this.

6 Further Analysis & New Modelling

6.1 Explanation of Return Periods and Levels of Protection

- 6.1.1 A 'rainfall event' is defined by peak intensity, duration and area covered. The return period (frequency) indicates the interval in which a particular rainfall event could be expected to be repeated or exceeded on average. This does not mean that a 1 in 10 year return period will only occur once every 10 years, but that it has a 10% chance of occurring in one year.
- 6.1.2 In England and Wales, the level of flood protection for new storm sewerage systems for new developments is set at a 1 in 30 year standard⁷ to operate without flooding. This is an industry design guideline and is not mandatory.
- 6.1.3 Many existing sewer systems in the UK offer considerably less than a 1 in 30 year

⁷ Sewers for adoption – WRc - Sixth Edition

protection as they have been built up over many years.

6.2 Levels of Service and the Limitations of the Modelling

- 6.2.1 In this section of the report references to “flooding” refer to storm waters discharging from ‘nodes’ (modelled manholes) on the sewerage network.
- 6.2.2 Ofwat use a measure called “the DG5 register” to explain the level of service provided by sewerage systems. The DG5 register has reference levels to record those properties and areas “At Risk” of internal or external flooding from 2 in 10, 1 in 10 and 1 in 20 year return period events.
- 6.2.3 The model used to inform this report is not suitable to express the level of service in DG5 terms because it does not accurately predict the flood volumes and overland flows that could result in internal or external flooding to properties or areas.
- 6.2.4 In fact the incidence of flooding predicted in the model is higher than the actual number of flooding events reported to Yorkshire Water (those events captured on the DG5 register).
- 6.2.5 Instead, this model predicts levels of flooding in the sewerage system from nodes. The model indicates the level at which the sewers are predicted to discharge (overflow) in different rainfall conditions. The flooding predicted from the nodes does not directly relate to property flooding but illustrates an escape from the sewerage system.
- We have therefore used the number of nodes at which flooding is predicted to occur to describe the performance of our network.
- 6.2.6 Consequently, a new verified integrated urban drainage model would be required in order to carry out an assessment of flood risk from the various sources, including the sewerage network. The model would need to take into account overland flood flows. A model of this type would require a substantial investment, for example data collection would include, but not be limited to, flow surveys, groundwater levels, asset surveys and would require different agencies working together. A study of this complexity could be expected to take in the order of 3 years to complete.
- 6.2.7 Yorkshire Water has advocated this approach in its dealings with stakeholders in Hull and will work with Ofwat to include this in its business plan.

6.3 Comparative Levels of Flood Protection

6.3.1 Modelling the network under different asset scenarios allows us to identify how the level of flood protection has changed over time. The scenarios that have been run through the model are as follows:

Scenarios	Description
Free discharge	A hypothetical scenario where the sewage pumping stations are removed from the model and the sewers are given a 'free discharge'. This allows the model to predict where flooding would occur even with unlimited pumping capacity and irrespective of tidal conditions
Pre Humbercare	East and West Hull SPS pumping regimes as they were pre Humbercare, excludes the transfer tunnel and Saltend Wastewater Treatment Works
June 2007	The sewerage system post Humbercare with East and West Hull SPS available for emergency use
Autumn 2009	The sewerage system once our announced investment is complete

6.3.2 The number of nodes predicted to flood in each scenario is used to provide the relative measure of the level of protection.

6.3.3 The modelling results for 1 in 10, 1 in 20 and 1 in 30 year storm events are set out in the table below.

Critical duration storm event**	free discharge		pre Humbercare		June 2007		Autumn 2009	
	modelled nodes with flooding	% of modelled nodes *	modelled nodes with flooding	% of modelled nodes *	modelled nodes with flooding	% of modelled nodes *	modelled nodes with flooding	% of modelled nodes *
1:10	87	2.5%	87	2.5%	89	2.5%	83	2.4%
additions from 1:20 run	34	1.0%	35	1.0%	94	2.7%	31	0.9%
additions from 1:30 run	47	1.3%	67	1.9%	81	2.3%	46	1.3%
TOTAL Nr of nodes with flooding > 100 cu. m for 1:30	168	4.8%	189	5.4%	264	7.5%	160	4.6%
nodes with no flooding	3332	95.2%	3311	94.6%	3236	92.5%	3340	95.4%

Notes on the model

The results have been reported to show the differences between the various scenarios. The model limitations mean that small differences are not significant and are within the accuracy of the model.

*A baseline figure of 3,500 modelled nodes has been used to evaluate the number of nodes with no flooding. The number of modelled nodes does increase slightly when changes to account for Humbercare are added.

**The critical storm duration for each return period has been selected that gives the worst case for each return period.

The performance of our drainage assets in Hull in June 2007

6.3.4 In summary, the model indicates that in June 2007, 92.5% of the modelled network had a level of flood protection greater than 1 in 30. This is a 2.1 percentage point decrease from the level of protection which existed pre-Humbercare.

6.3.5 Our report shows that:

- For the critical (short) duration '1 in 10' return period storm, in June 2007, no flooding is predicted from 97.5% of modelled 'nodes' (manholes). This is the same level of protection which existed pre-Humbercare.
- For the critical (long) duration '1 in 20' return period storm, in June 2007, no flooding is predicted from 94.8% of modelled 'nodes' (manholes). This is a 1.7 percentage point decrease from the level of protection which existed pre-Humbercare.
- For the critical (long) duration '1 in 30' return period storm, in June 2007, no flooding is predicted from 92.5% of modelled 'nodes' (manholes). This is a 2.1 percentage point decrease from the level of protection which existed pre-Humbercare.

Expected performance of our drainage assets in Hull by Autumn 2009

6.3.6 In summary based on the modelling, we conclude that the level of protection will be at least equal to pre-Humbercare levels. Our report shows that:

- For the critical (short) duration '1 in 10' return period storm, in Autumn 2009,

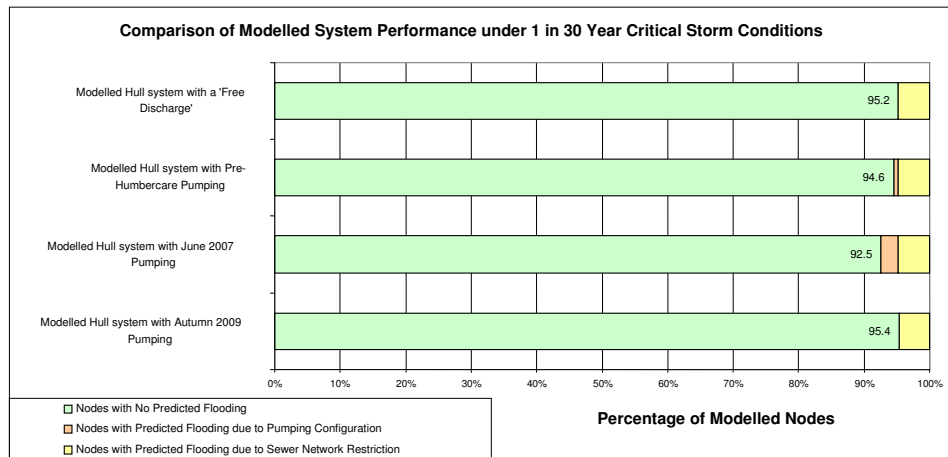
no flooding is predicted from 97.6% of modelled 'nodes' (manholes). This is a marginal improvement on the level of protection which existed pre-Humbercare.

- For the critical (long) duration '1 in 20' return period storm, in Autumn 2009, no flooding is predicted from 96.7% of modelled 'nodes' (manholes). This is a 0.2 percentage point improvement on the level of protection which existed pre-Humbercare.
- For the critical (long) duration '1 in 30' return period storm, in Autumn 2009, no flooding is predicted from 95.4% of modelled 'nodes' (manholes). This is a 0.8 percentage point improvement on the level of protection which existed pre-Humbercare.

'Free Discharge' Scenario Modelling (Hypothetical Unlimited Pumping)

6.3.7 The 1 in 30 year data demonstrates that network restrictions are also a major influence on the level of flood protection. Whilst changes in pumping capacity will impact on the level of protection, it is apparent from the model that even at the free discharge level, flooding is predicted to occur. This is similar to other urban drainage systems.

6.3.8 The following chart demonstrates that our investment will ensure that the level of protection provided is equivalent to that provided under the free discharge scenario, meaning that our investment will effectively maximise the contribution that pumping can make to flood protection in Hull, and that the remaining predicted incidents of flooding are due to long standing network capacity constraints in the network.



7 Bransholme Surface Water Pumping Station (Bransholme SWPS)

7.1 Background

- 7.1.1 This section covers the performance and operation of Bransholme SWPS on June 25th 2007 and outlines the improvements already under construction.
- 7.1.2 Bransholme forms the most northerly part of Hull and is hydraulically isolated from the remainder of the city's drainage infrastructure. Like much of the surrounding area, the land is low lying and consequently the sewage and surface water are pumped from the catchment by two pumping stations situated just to the east of the flood defences along the banks of the River Hull. These are identified in the photograph below.



- 7.1.3 In contrast to the rest of Hull, Bransholme has separate systems to deal with surface water and sewage.

Sewage flows are carried to a pumping station which then forwards these flows in to the Humbercare sewerage system and ultimately to Saltend. These flows account for approximately 1% of the pumping capability of the Humbercare sewerage system.

Storm water is conveyed to a second pumping station (Bransholme SWPS) which most of the time pumps water direct to the River Hull. However, when the river levels become elevated, the storm water is redirected to a large storm water lagoon sited along the banks of the river. It is this second pumping station which is important to maintain the level of flood protection of the Bransholme area.

7.2 Our Bransholme SWPS Response on June 25th 2007

7.2.1 On June 25th 2007 Bransholme SWPS was operating. By the morning of the June 26th, Bransholme SWPS itself had been inundated with floodwater. At this point equipment critical to the operation of the station became submerged resulting in the failure of the pumps themselves.

7.2.2 Yorkshire Water has contingency plans in place for access to mobile temporary pumping equipment through its suppliers and contract partners. These plans were instigated during the events of June 2007, but were impacted by events occurring elsewhere in the region.

7.2.3 Yorkshire Water was able to recommence pumping at the Bransholme SWPS within 12 hours of the failure and had restored the pumping capacity within 26 hours.

7.3 Post Flood Investment in Bransholme SWPS

7.3.1 Since June 25th 2007 Yorkshire Water has completed the following maintenance investment at Bransholme SWPS to ensure that the existing equipment is more robust:

- The starter and control system has been reinforced
- Enhanced cooling systems have been introduced to improve resilience in the event of prolonged periods of operation.

However, Yorkshire Water is currently in the final stages of installing an additional 5.4 cumecs of pumping capacity at Bransholme SWPS. This will be in the form of 2 submersible pumps each of 2.7 cumecs capacity. These are intended to provide 100% back up capability in the event of the existing pumps failing under exceptional circumstances similar to June 2007. Current plans are for this additional equipment to be ready for operation by the end of July 2008.

7.3.2 As a result, Bransholme SWPS will be more resilient during extreme storm events.

7.3.3 We have maintained regular discussion throughout the proposed development of the Kingswood area with Kingswood Parks, Hull City Council and the Environment Agency to assess the impact on the Bransholme pumping regime.

8 The Future

8.1 Integrated urban drainage management will provide better solutions

- 8.1.1 A consistent theme of the investigations since last year's event is the requirement for more joined up strategic planning in the design and management of urban drainage systems. This is particularly important in Hull given the nature and complexity of the system and the historical reliance on pumped drainage, which pre-dates the Humbercare system.
- 8.1.2 Yorkshire Water supports the conclusions of DEFRA's 'Making Space For Water' report published in March 2005, which recommends an integrated approach to urban drainage management and the Pitt Review Team's recommendations for multi-agency working.
- 8.1.3 The modelling work demonstrates that increasing pump and sewer capacity is not the only answer to longer term surface water management and flood mitigation in the city.
- 8.1.4 Yorkshire Water believes that multi-agency solutions based around new modelling which accurately predicts the impact of surface and ground water flows in Hull is a necessary first step. This is a clear recommendation of the 2008 MWH study and the Arup report. A series of senior level meetings have taken place between Yorkshire Water, Hull City Council, East Riding of Yorkshire County Council and the Environment Agency, and as a result all responsible agencies have agreed to a high level steering group to create an over-arching strategy for surface water management in the city, with the first meeting arranged for September.
- 8.1.5 Yorkshire Water will propose to Ofwat in its forthcoming business plan the investment needed for the period 2010 – 2015 to maintain and improve the sewerage systems in Hull. This will include the completion of the strategic multi-agency study. This multi-agency working is still at an early stage and the detail, scale and cost of our contribution to a long term integrated solution is unknown. Consequently, we have started preliminary discussions with Ofwat about the mechanisms which need to be put in place to allow the company to fund any major improvements to the level of protection for Hull within the 2010 – 2015 investment cycle.
- 8.1.6 Whilst the events in Hull during 2007 were extreme, we believe that lessons can still be learned by all parties and Yorkshire Water is committed to playing its part to help protect Hull and adjoining areas in the future.

