Making Space for Water

Upper Ouseburn catchment

Upper Ouseburn catchment: taken from Google Earth

Report on hydrometry installed by Newcastle University and analysis of current data

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1. Introduction

Prior to the Making Space for water project, there was a limited hydrometry network within the upper Ouseburn catchment. The Ouseburn had two flow gauges and a scattering of tipping bucket raingauges. The flow gauges did not give a good representative view of urban runoff and the raingauge network did not capture rainfall totals for convective events. This was such the case for the June 2005 event where the EA raingauge network did not capture the rainfall event which flooded the Red House Farm estate. Apart from rainfall and stream hydrometry, Newcastle University installed a depth recorder within the large Sustainable Urban Drainage System (SuDs) pond of cell I on Newcastle Great Park development site. This diver was to understand how well the SuDs were performing and also to understand the interaction between the SUD and the Ouseburn. This report concentrates on the improved hydrometric network installed by Newcastle University and the one year worth of data is analysed to understand the hydrological patterns of the upper Ouseburn catchment.

2. Tipping bucket raingauges within the Upper Ouseburn catchment

It is important to understand the amount of precipitation falling in a catchment to fully understand the resulting stream hydrology and its use in flood forecasting models. However, in practice most catchments have a sparse raingauge network which fails to accurately capture the spatial and temporal variability of a storm. This was the case for the Ouseburn catchment which had a poor raingauge network. As a result, the existing network failed to capture the spatial complexity of the June 2005 Red House Farm estate flood.

AIM: - To increase the raingauge network in the Upper Ouseburn catchment to produce a dense raingauge network that combines both Newcastle University raingauges and Environment Agency raingauges.

Under the making space for water project, Newcastle University installed three tipping bucket raingauges from May 2006. All raingauges are of a tipping bucket system and were built by Environmental Measurements Ltd and are certified by the Centre of Ecology and Hydrology. These three raingauges and corresponding hyetographs are summarised as follows:

2.1. Brunton Bridge Farm raingauge

RAINGAUGE	E	N	Elevation (m)
Brunton Bridge Farm	421362.136	569897.206	54.9

Picture 2.1 – Brunton Bridge Farm raingauge

The Brunton Bridge Farm raingauge is located towards the side of a field nearby the local farm house. The raingauge is located near to the Brunton Bridge level gauging station. This site not only provides excellent security but also has limited obstructions nearby such as trees or housing. The raingauge has had no problems since installation and therefore has a complete record. Daily rainfall data is presented in Figure 2.1.

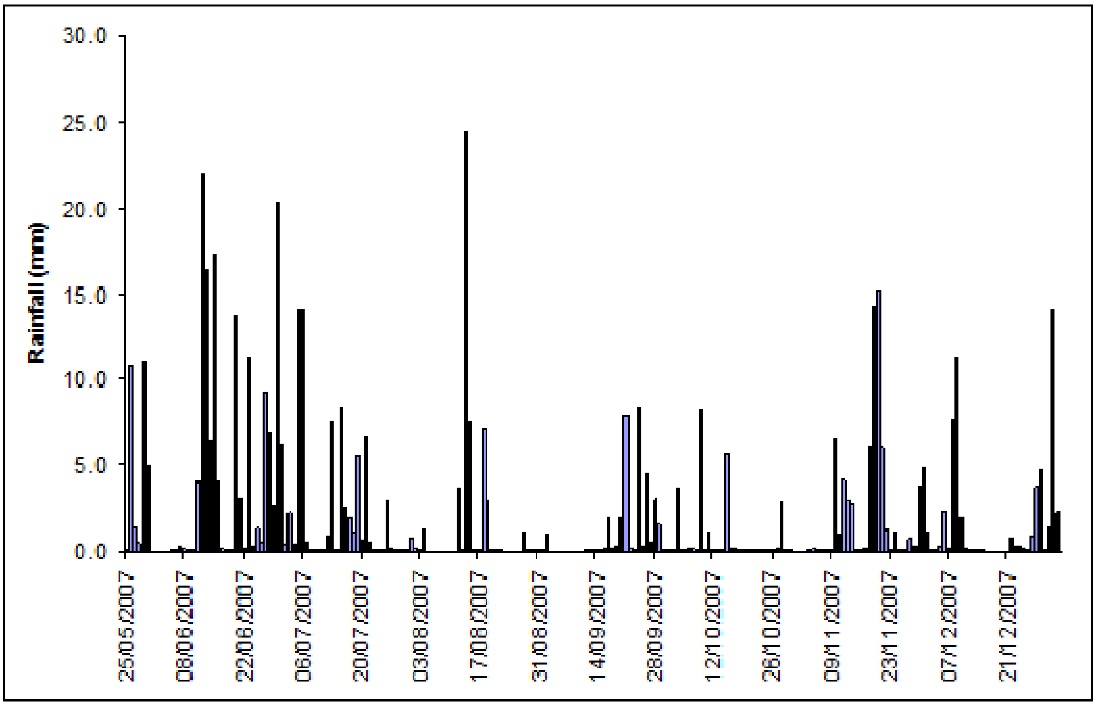

Figure 2.1 – Daily rainfall hyetograph for the Brunton Bridge Farm Raingauge

2.2. Sage Raingauge

RAINGAUGES	E	N	Elevation (m)
Sage	422386.986	571258.160	71.1

The Sage offices provided the ideal location for a raingauge in the urban environment due to the high security presence at this site. A small bare garden area provided the only site for the raingauge as most of the Sage office site is concrete or tarmac which provides a difficulty in attaching the raingauge to the ground.

The Sage raingauge has limited data set for the summer period of 2007. This was due to logger problems and blockages within the gauge over a combined period. As a consequence no rainfall data was recorded during the period from 15th June to 15th September.

2.3. Three Mile Bridge (City of Newcastle golf course) raingauge

RAINGAUGES	E	N	Elevation (m)
Newcastle Golf Course	424150.552	569398.176	49.9

Photo 2.2 – Three Mile Bridge raingauge

The Three Mile Bridge raingauge is located within the City of Newcastle golf course in Gosforth. The golf course green provides an open landscape for the gauge and also provides ideal security for the gauge due to being located near the club hut. The gauge is located next to the Three Mile level gauging station. The gauge has had a complete record since installation in May 2007 (until last download in January 2008). Daily rainfall data for the Three Mile raingauge is presented in Figure 2.2 along with varying time steps in Figure 2.3.

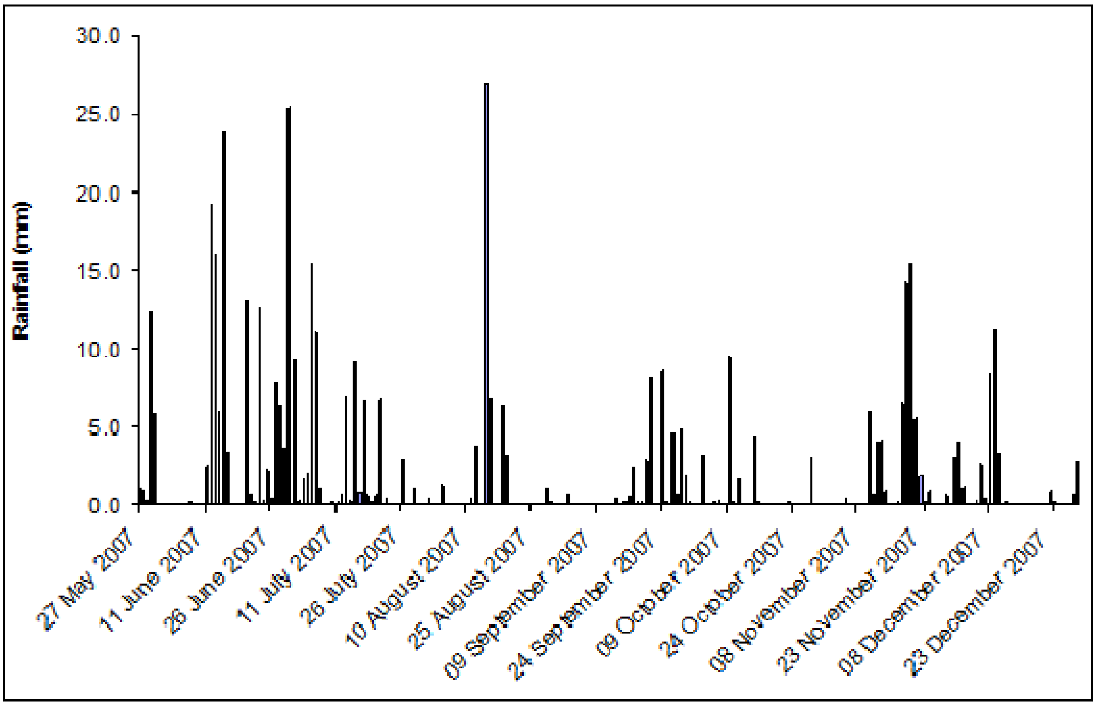

Figure 2.2:- Daily rainfall hyetograph for the Three Mile raingauge

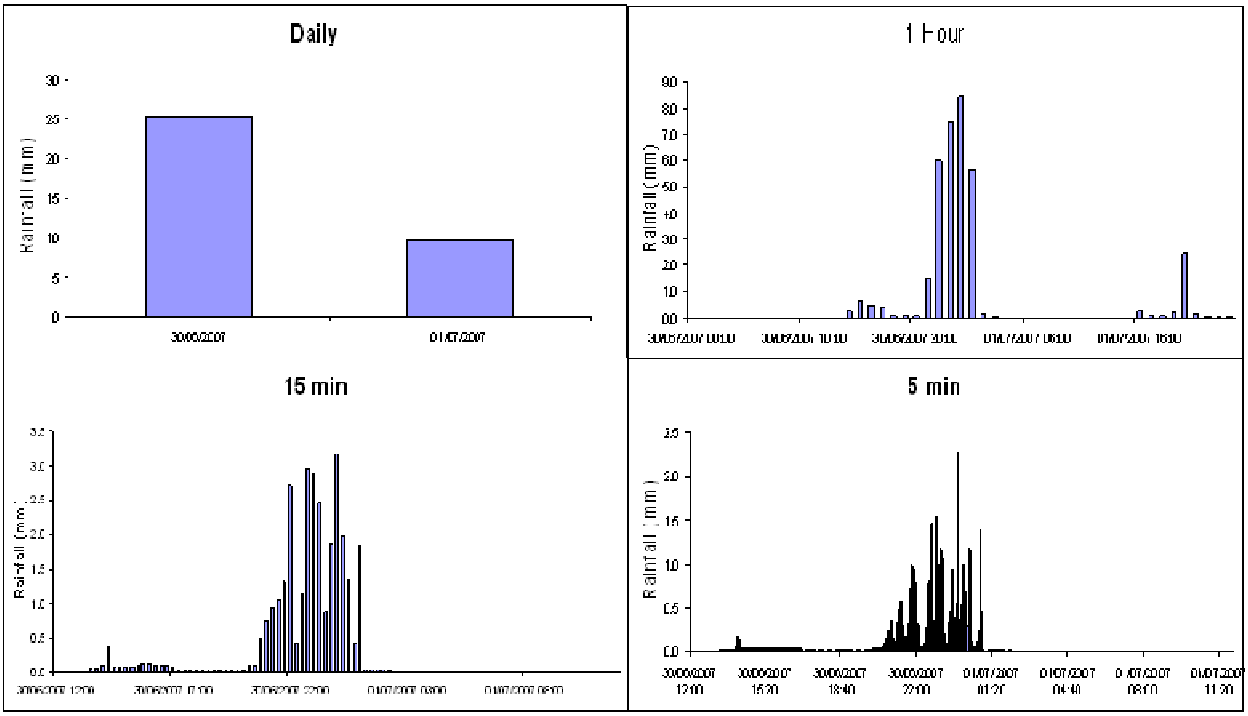

Figure 2.3:- Data from the 1st July 2007 storm event from the Three Mile raingauge. The four diagrams above show how a tipping bucket raingauge system can display temporal variability with storm events

2.4. University Gardens (Claremont Rd) Raingauge (OFFLINE)

The University Gardens raingauge, located on Claremont road was also installed in May 2007 but was vandalised within one month. The gauge was therefore removed due to the poor security at the site. This highlights the importance of security issues of urban raingauges.

The red squares on Figure 2.4 indicate the locations of all the current raingauges installed by Newcastle University in the upper Ouseburn catchment.

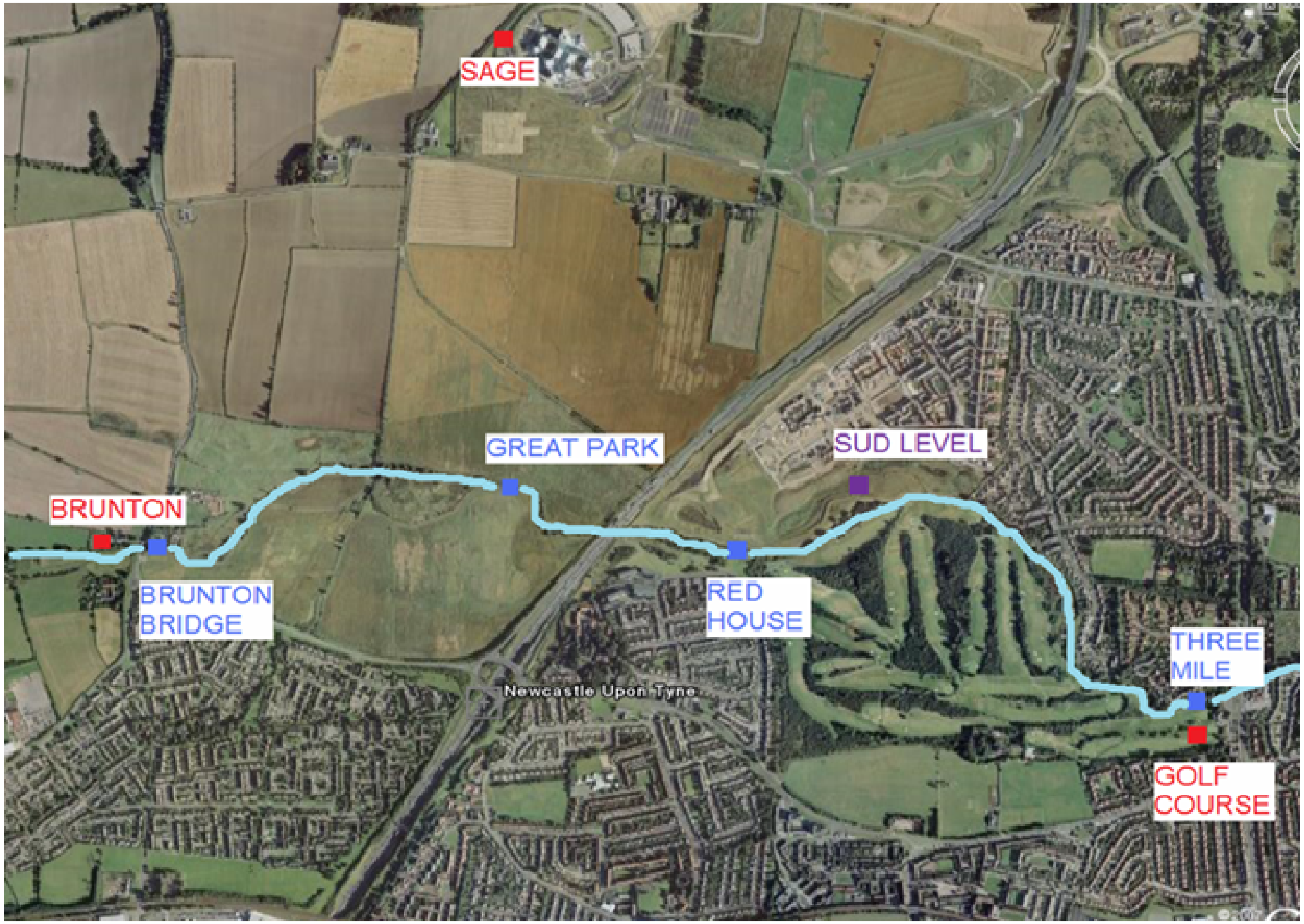

Figure 2.4:- An areal photo displaying the location of Newcastle University Hydrometry in the upper Ouseburn catchment where red squares are raingauges, blue squares are gauging stations and purple squares are SUD water level loggers (Taken from Google Earth).

3. Gauging stations within the upper Ouseburn catchment

This section will look at the hydrometry installed within the Ouseburn channel and Cell I SUD. Rating curves for these stations will be examined along with flow data.

3.1. Stream and SUD hydrometric network installed in the upper Ouseburn

To understand the effect of major land use change in the catchment on the upper Ouseburn stream hydrology, four gauging points have been installed along the water course. These gauging stations consist of a pipe stilling well attached to the side of the bank and within the stilling well a ‘diver’ pressure transducer (produced by Vanessen instruments) measures the total pressure of water and atmosphere above it. Using a barometer diver to take away the effect of atmospheric pressure, the water level above the diver can be measured. The accuracy of the diver is within 0.1% and has a resolution of 0.1cm. The diver also measures stream temperature (however this is a point measurement and not a stream profile measurement). No structure (weir or flumes) have been installed in the Ouseburn. Figure 2.4 displays the locations of all the four gauging stations (blue squares). Apart from a fault with the barometric diver (used for corrections) from the 1st December 2007 to 4th December 2007, a full stage data record is available for all sites.

Table 3.1: Locations and cap elevations of the four gauging stations installed by Newcastle University in the upper Ouseburn catchment

STREAM GAUGES			
Location	**E**	**N**	**Cap elevation (m)**
Brunton Bridge	421477.172	569884.006	55.073
Kingston Park (Great Park)	422404.344	570057.765	50.488
Red House Farm	422969.138	569880.964	50.357
Three Mile Bridge	424183.397	569485.994	49.032

3.1.1. Brunton Bridge

Brunton Bridge gauging station was installed just below Brunton Bridge, hidden behind some shrubs on the bank of the Ouseburn for security. Brunton Bridge is the smallest catchment measured by Newcastle University in the upper Ouseburn nested gauging station system. The catchment is predominantly rural above this gauging station making this station ideal for understanding the rural hydrology of the upper Ouseburn catchment. The stage record is summarised in Figure 3.1.

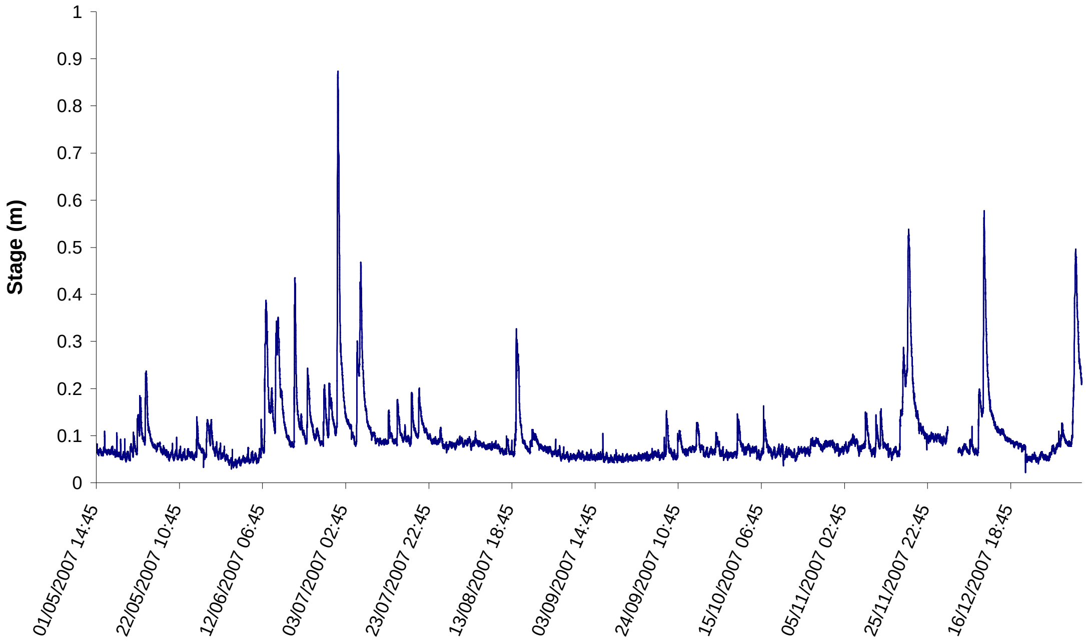

Figure 3.1:- Stage record at the Brunton Bridge gauging station

3.1.2. Kingston Park (Great Park)

The Kingston Park (beside the great park development) is just below the concrete access bridge to the great park development and the Kingston Park outlet. This gauging station is downstream of the Brunton Bridge station and upstream of the Red House Farm station. The diver is hidden behind a fence for added security. The stage record is summarised in Figure 3.2 along with a diagram of the instrumentation set up (Figure 3.3).

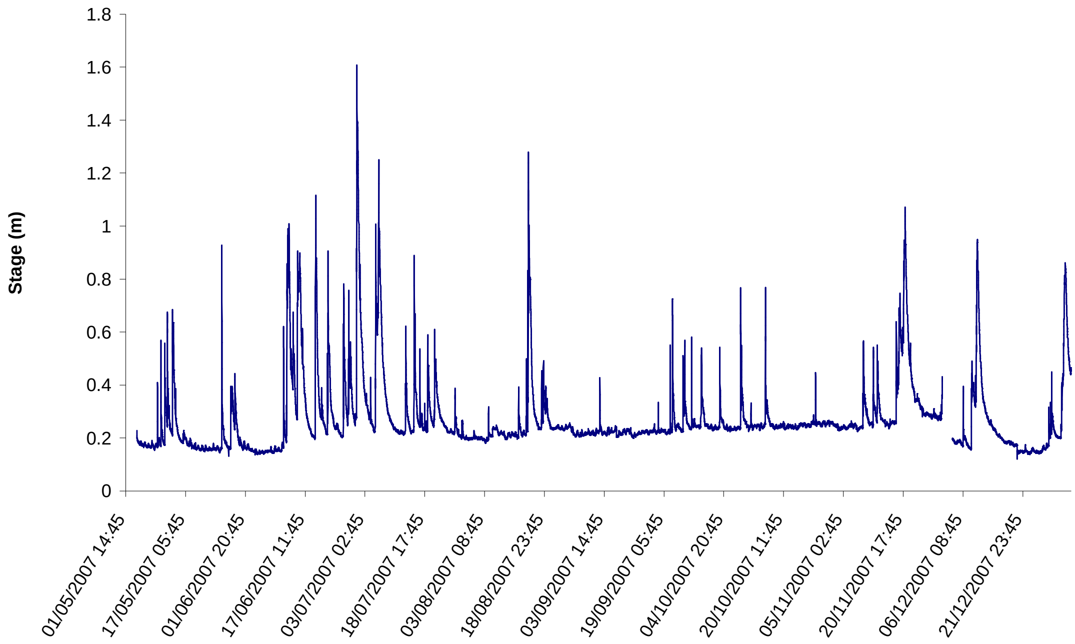

Figure 3.2: Stage record for the Kingston Park gauging station

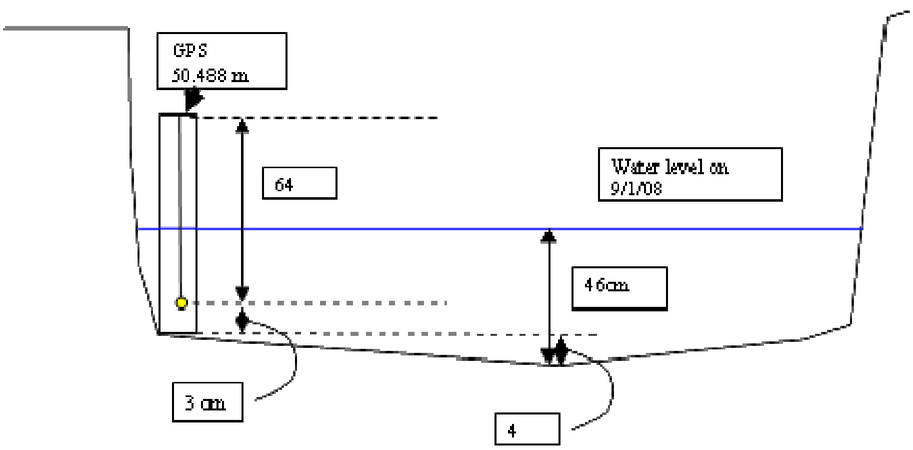

Figure 3.3: Instrumentation set up at the Kingston Park gauging station.

3.1.3. Red House Farm estate

The Red House Farm gauging station is located below two water surface outfalls. The station is downstream of Kingston Park and upstream of Three Mile Bridge. Due to the channel shape and issues with security, the stilling well tube is located on a small ledge in the channel. For added security the diver string can only be accessed with a specially designed hook to stop people removing the logger. The stage record is summarised in Figure 3.4.

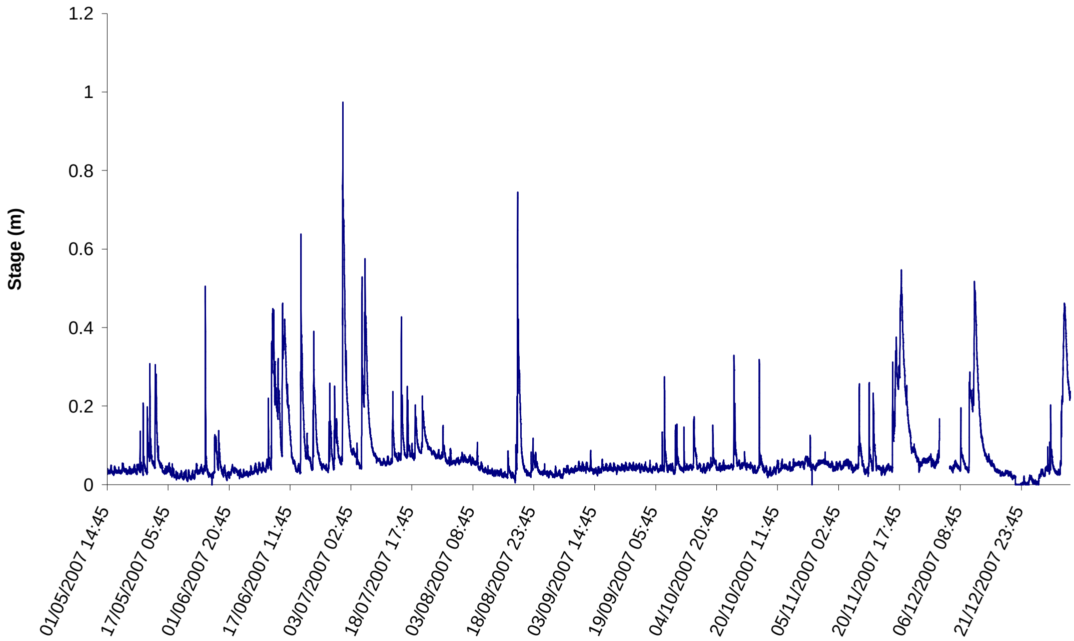

Figure 3.4:- Stage record at the Red House Farm gauging station

3.1.4. Three Mile Bridge

The Three Mile gauging station is located 50m downstream of the new Northumbrian Water outfall. The station is located within the city of Newcastle golf course which helps with security of the site. The station is the largest catchment monitored by the Newcastle University instrumentation. The stage record is summarised in Figure 3.5.

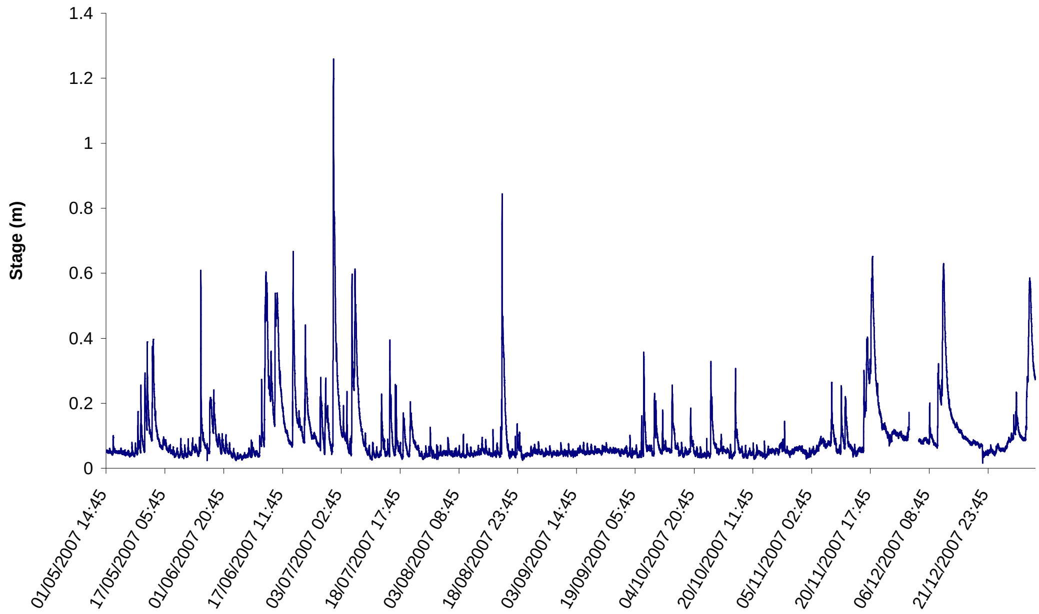

Figure 3.5:- Stage record from the Three Mile Bridge gauging station

3.1.5. Cell I SUD water level recorder

In January 2008 a water level recorder was installed in the large SUD beside the Red House Farm gauging station. This water level recorder will indicate how the SUD interacts with the Ouseburn.

SUD water level recorder	E	N	Cap elevation (m)
SUD outlet	423340.850	570100.530	49.039

3.1.6. Catchment areas

Catchment areas from all the above catchments and the EA station at Woolsington are presented in Table 3.2

Table 3.2: Upper Ouseburn surface catchment areas

Catchment	Area (km^2)
EA Woolsington	9.0
Brunton Bridge	17.6
Kingston Park	22.6
Red House	25.2
Three Mile Bridge	29.8

However, it must be considered that in Table 3.2 catchment areas are derived from surface elevations. The catchment areas in Table 3.2 do not take into account the sub-surface drainage area. Therefore it is likely that the catchment areas presented here carry an element of uncertainty due to drains and sewers beneath the ground.

3.2. Rating curves for gauging stations

Each gauging station records stage and this can be converted into flow by the use of a rating curve. To produce a rating curve flow gauging must be performed at different water levels in the river Ouseburn. These points are plotted and then this curve can be used to derive flow. Most gauging points were performed by Andrew Quinn as part of his MSc thesis (using a current meter). Recently the University has been able to use its ADCP (Acoustic Doppler Current Profiler) (Photo 3.1) in the Ouseburn. The ADCP creates a flow profile which is more accurate than a current meter and each gauging can be performed quicker (Figure 3.7). Development of the rating curve is on-going as it is essential to capture both high flows and low flows. However, this is a difficult task and you must have an idea in advance when the peak flow will occur. Current rating curves are displayed in Figure 3.6. The rating curves were derived using a power law model.

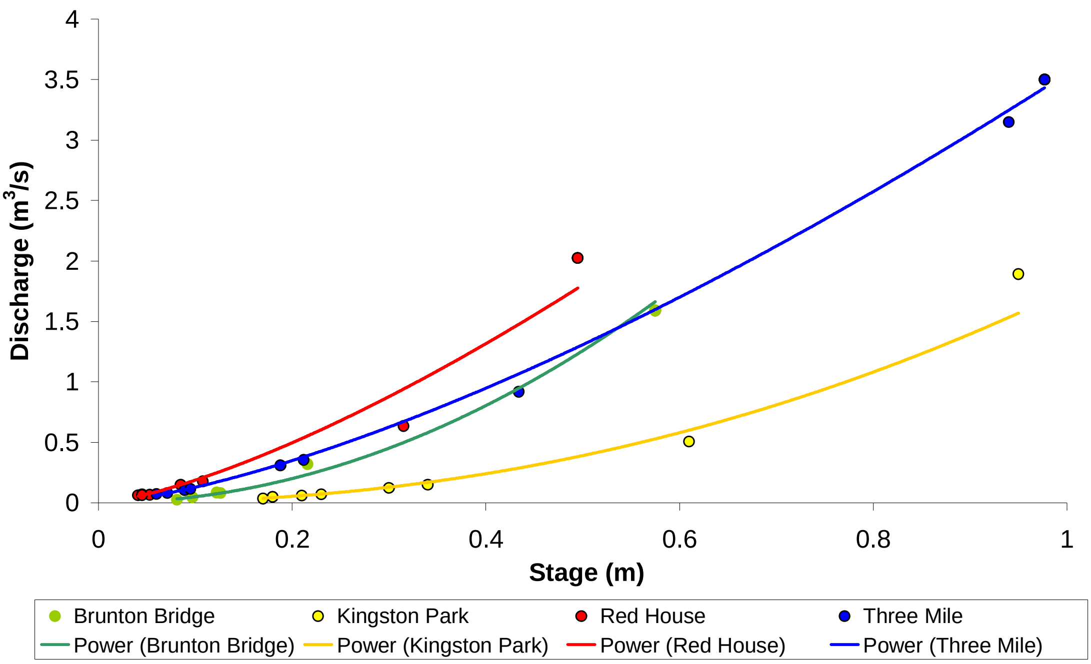

Figure 3.6:- Rating curves for the four gauging stations. The Kingston Park rating curve has been extrapolated to show the problems with using extrapolations for predicting high flows.

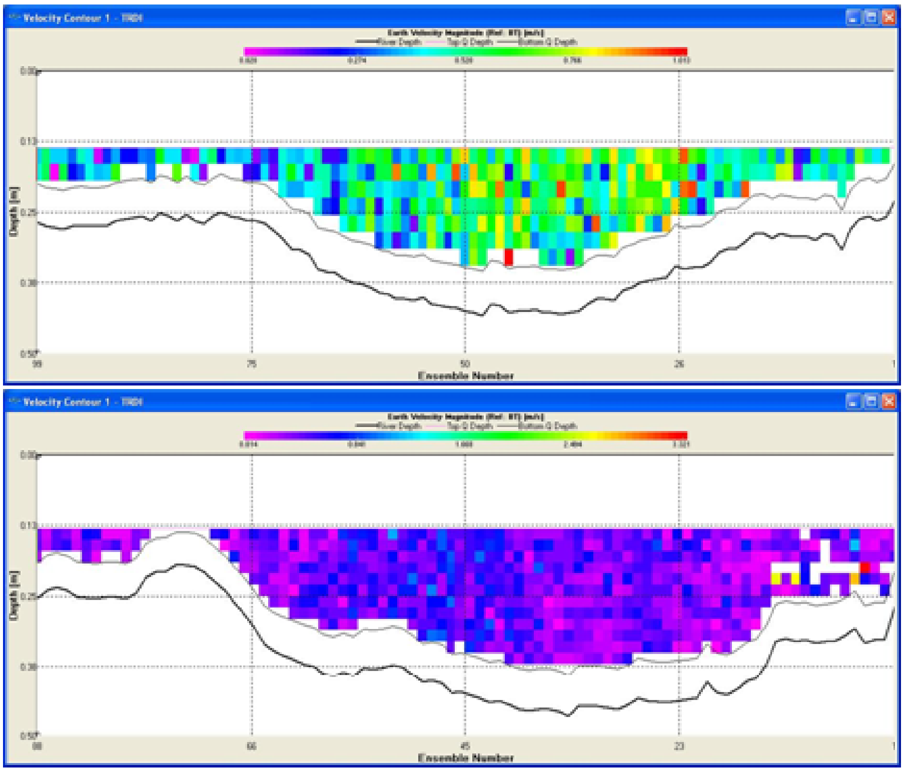

Figure 3.7: ADCP profile of Three Mile Bridge (top) and Brunton Bridge (bottom)

Photo 3.1: ADCP in action

These rating curves have been applied to the stage data to produce flow; this data is presented in Figure 3.8.

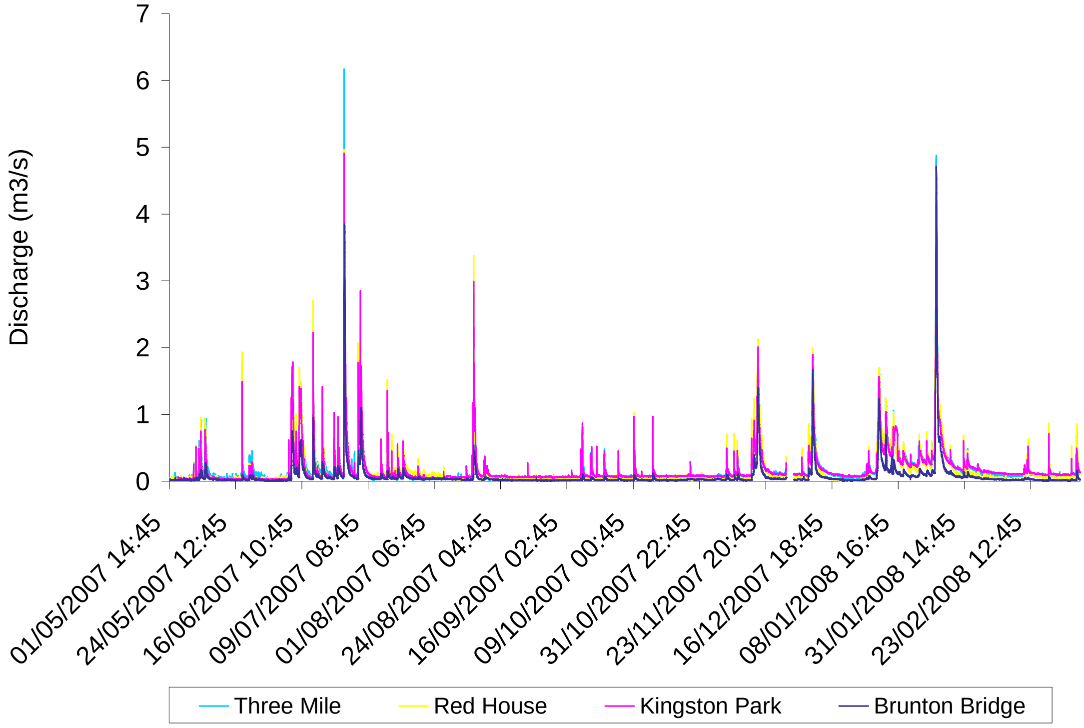

Figure 3.8:- Discharge values for the four gauging stations in the upper Ouseburn catchment

Figure 3.8 highlights some interesting observations; these are:

- The rating curves need to be improved: both at high flows to capture the peak (as highlighted in Table 3.3-4) and also to improve low flows. Gauging must still be carried out to validate the extrapolation of the rating curves;
- Peak discharge varies between Kingston Park and Red House; this shows that the SUDs between these two gauging stations may be playing a part in the hydrology. The SUD water level recorder will indicate how the SUDs influence the flood peaks in the Ouseburn.

Table 3.3: A summary of the highest flow gauging values compared to highest measured stage

Site	**Rating curve peak flow (m^3/s)**	**Highest gauged flow (m^3/s) (highest gauging as a percentage of peak extrapolated flow)**	**Stage at highest gauged flow as a percentage of peak recorded stage**
Brunton Bridge	1.59	4.71 (33.8%)	60.0%
Kingston Park	1.89	4.91 (38.5%)	59.0%
Red House	2.02	4.96 (40.7%)	50.8%
Three Mile	3.50	6.17 (56.7%)	77.6%

Table 3.4: A summary of the lowest flow gauging values compared to lowest measured stage

	Lowest level at gauging (m)	Lowest recorded level (m)
BRUNTON	0.081	0.022
KINGSTON	0.17	0.12
RED HOUSE	0.041	0
THREE MILE	0.060	0.016

4. Ouseburn high flow data analysis

4.1. High flow data analysis

The flow gauge network within the upper Ouseburn has collected just under a years worth of data. During this period the flow network has monitored three high flow events. Since the period of data is short it was always going to be likely that a major flood event was not captured within this year. However, data from the three high flow events show interesting patterns about the Ouseburn hydrology.

4.1.1 High flow event – 1st July 2007

The 1st July 2007 high flow event was the result of an overnight downpour. This rainfall was not localised and was widespread over Newcastle upon Tyne. However, the rainfall was more intense towards the East and within the city centre, this trend is highlighted in Table 4.1.

Table 4.1: Rainfall summary for each of the largest storm events over the Ouseburn from May 2007 – April 2008 with a summary standard deviation of the storm totals

	30/06/07 2000 - 01/07/07 0300	**14/08/07 1700 - 14/08/07 2100**	**31/12/07 2000 - 02/01/08 1100**	**21/01/08 0600 - 21/01/08 2000**
Brunton Bridge	20.5	14.6	17.4	-
Sage	-		19.9	27.8
Three Mile	29.3	17	-	-
Jesmond	35.2	16.6	15.8	-
Darras Hall	13	6.8	21.8	-
Farne School	20	14	19.4	-
S.D.	**8.7**	**4.1**	**2.3**	-

Previous to this storm, the catchment had had a fairly dry couple of weeks and the rural soils still had plentiful capacity to store water. Data presented in Figure 4.1 shows the flow in the Ouseburn for the 1st July 2007 at the upper Ouseburn gauging stations. Figure 4.2 presents the flow data from Three Mile

Bridge (as seen in Figure 4.1) along with a rainfall hyetograph from the Three Mile Bridge raingauge.

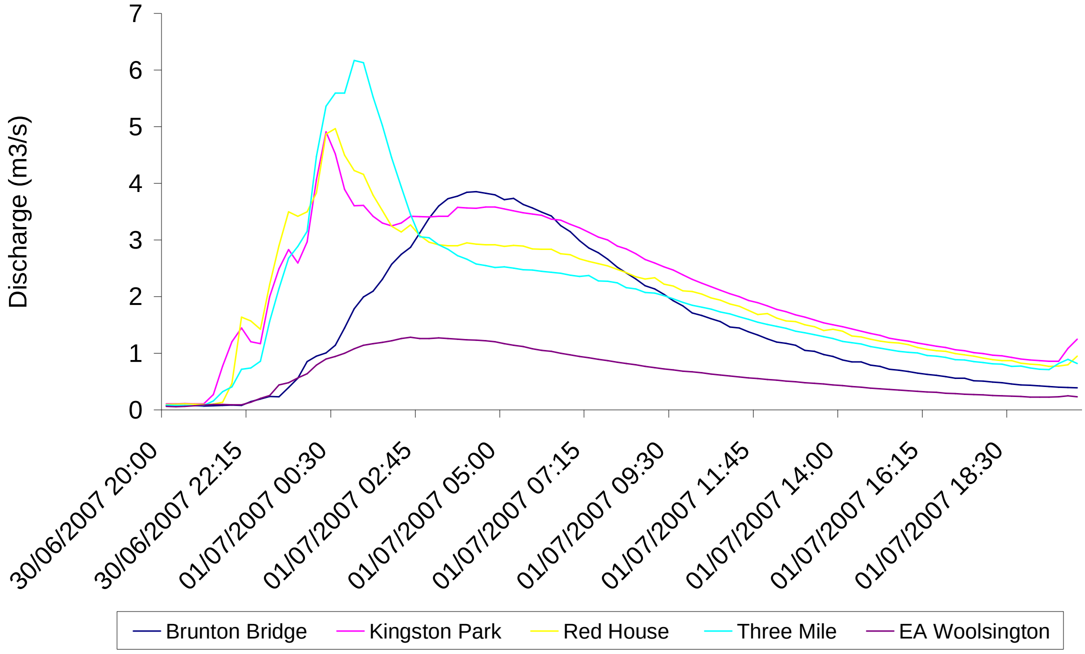

Figure 4.1: The 1st July 2007 storm hydrograph for the five upper Ouseburn gauging stations (EA Woolsington included, which is upstream of Brunton Bridge).

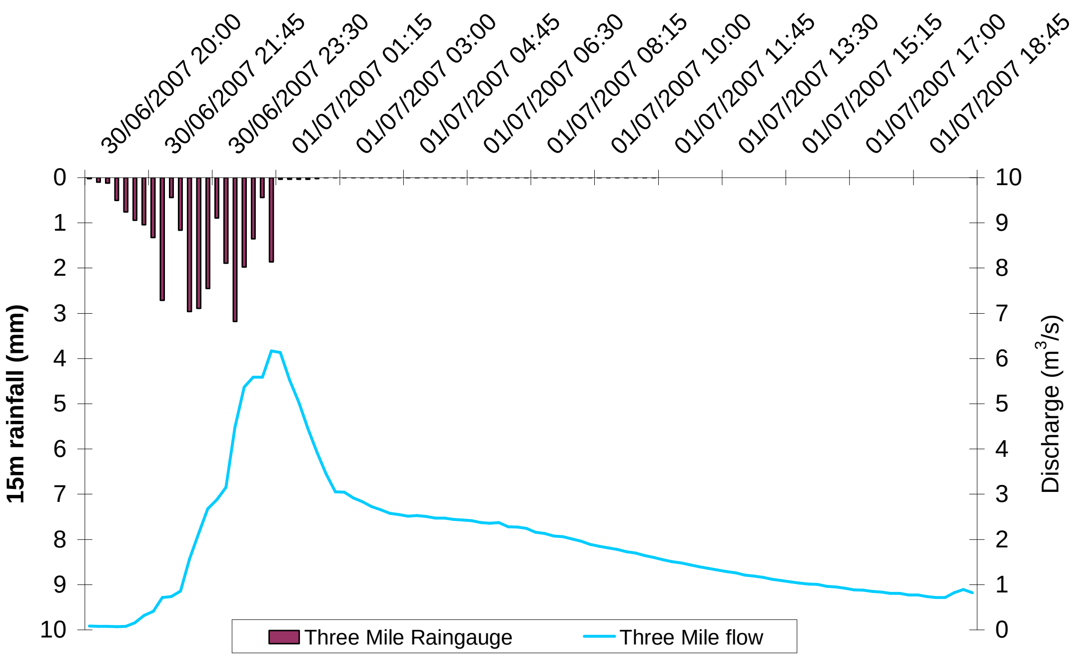

Figure 4.2: Rainfall and Three Mile bridge discharge for the 1st July 2007 storm event

Key findings from the 1st July 2007 high flow events are:

- It was a high intensity rainfall event which occurred over a short period of time;
- The rising limb of the Kingston Park, Red House and Three Mile hydrograph is flashy (Figure 4.1). However the Brunton Bridge and Woolsington rising limbs are fairly shallow and slow to rise. This suggests that the runoff rate of the urban catchments is higher than the rural catchment;
- The times of peak of the downstream gauging stations Kingston Park, Red House and Three Mile are quicker than the times of peak of the upstream Brunton Bridge and Woolsington catchments. Rainfall patterns suggest that there was little spatial variability within the upper Ouseburn catchment (Table 4.1). This therefore suggests there was more runoff from the urban catchments (downstream) than from the rural catchment. The rural catchment was therefore slower to respond to the rainfall. This suggests the rural catchment was storing water;
- The rural peak can be seen on the urban catchment hydrographs as a bump on the falling limb. This shows the flood attenuation downstream;
- The flow at Kingston Park is similar to the flow at Red House Farm. This indicates that an increased amount of runoff is occurring from the Kingston Park catchment.

The rating curves, however, need more calibration at high flows to be sure of this and If the rural flood peak occurred at the same time as the urban peak then the flood would be much larger.

4.1.2. High flow event - 14th August 2007

The rainfall patterns on the 14th August 2007 where similar to that of the 1st July. Widespread rainfall fell across Newcastle upon Tyne over a short period of time. The main storm was widespread but there is evidence to suggest that the beginning of the storm was a result of localised convective events. This can be seen at the beginning of the hydrograph on Figure 4.3. Examining this more closely (Figure 4.5) shows how the flow originates from Kingston Park and the peak attenuating downstream.

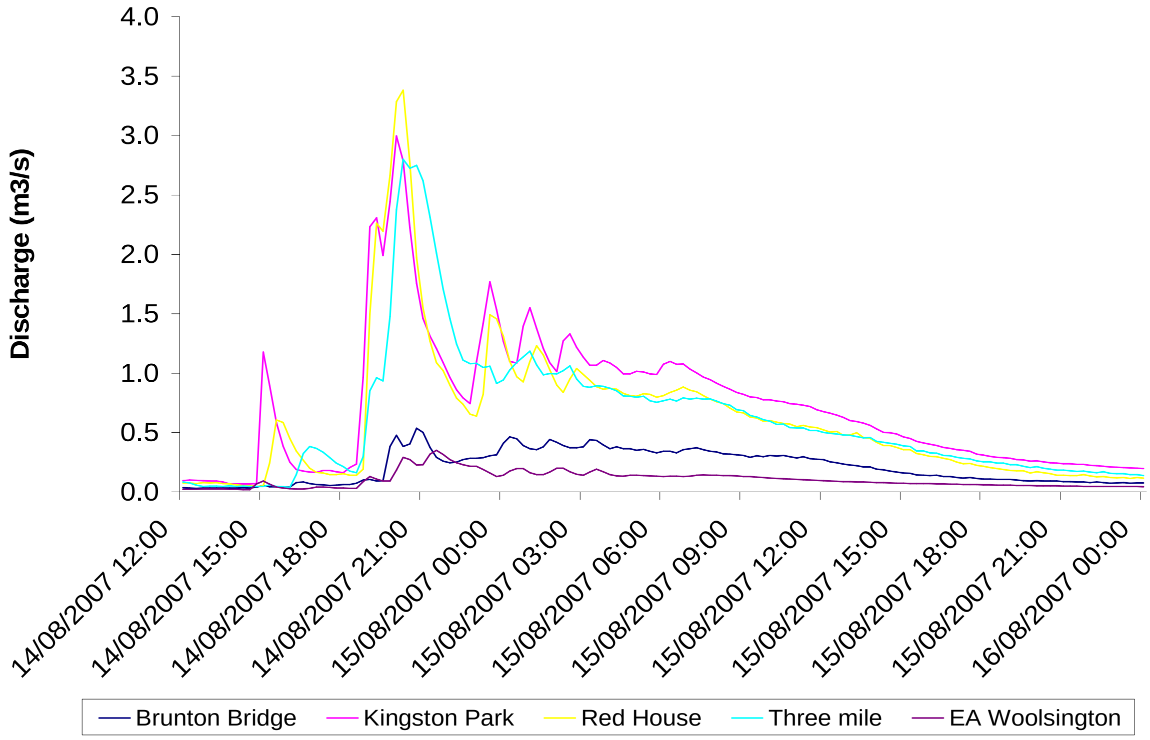

Figure 4.3: The 14th August 2007 storm hydrograph for the five upper Ouseburn gauging stations (EA Woolsington included, which is upstream of Brunton Bridge).

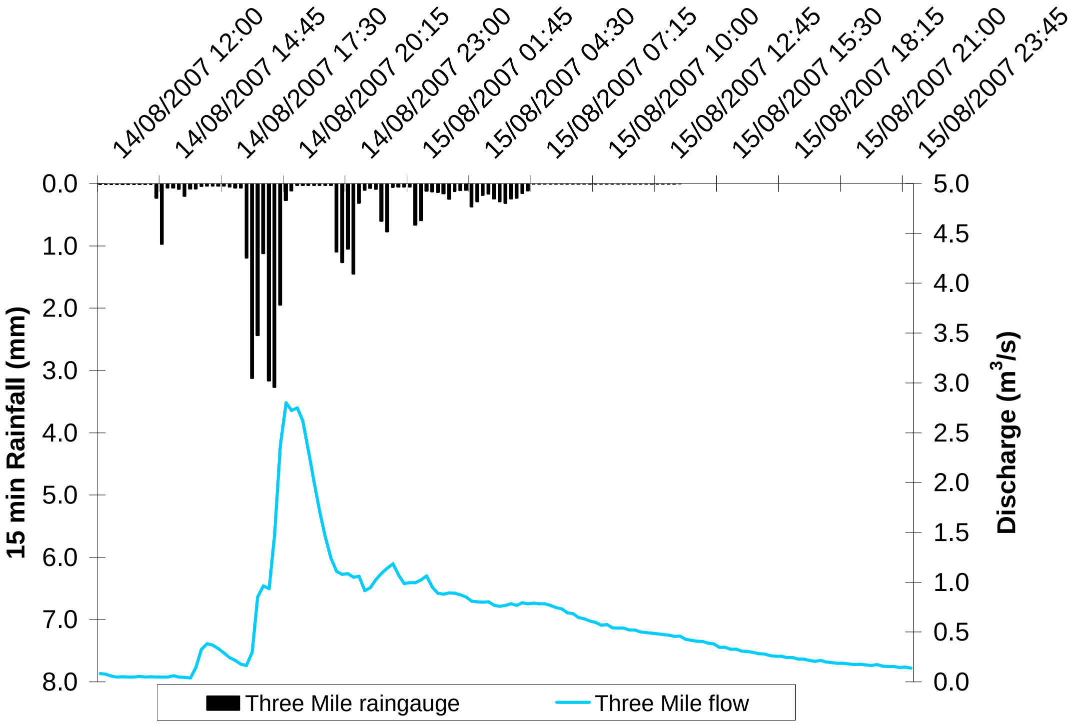

Figure 4.4: Rainfall and Three Mile bridge discharge for the 1st July 2007 storm event

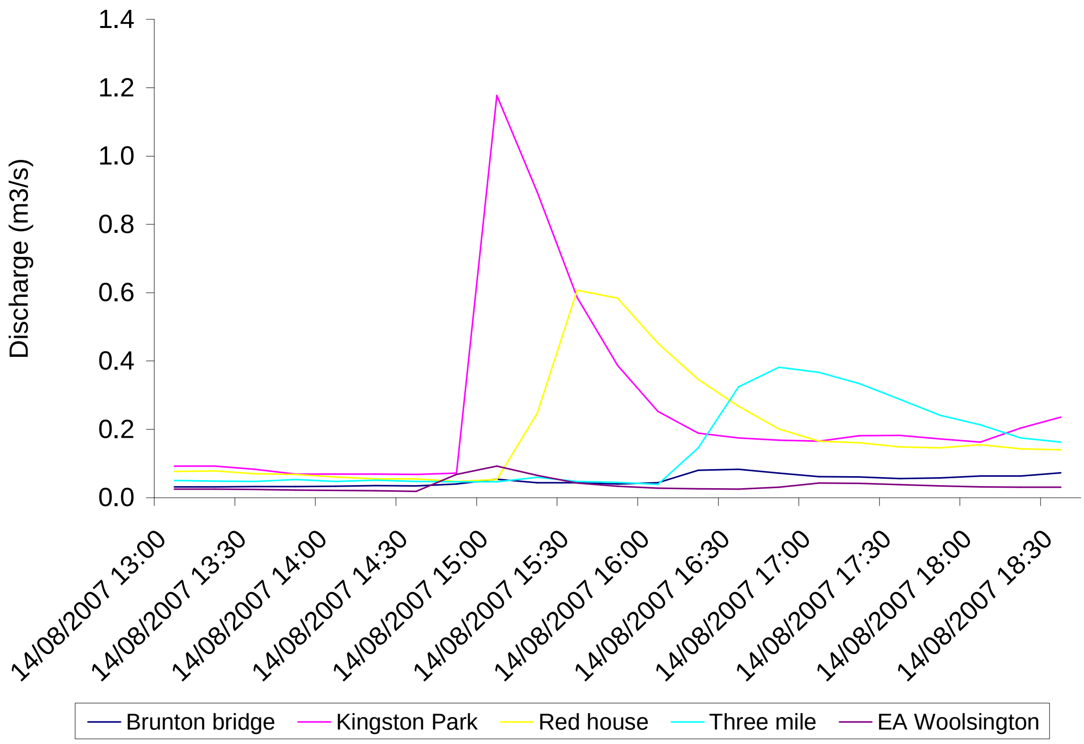

Figure 4.5: The beginning section of the 14th August 2007 storm hydrograph for the five upper Ouseburn gauging stations (as seen at the start of Figure 4.3)

Key findings from the 14th August 2007 event are:

- This was an intense convective event which covered the whole of the upper Ouseburn catchment. The duration of this event was shorter than the 1st July 2007. Rainfall over the rural upstream catchment was a little less than downstream (Table 4.1). Catchment antecedent conditions were drier than the 1st July 2007 storm (there was a little rainfall two weeks before the storm);
- An initial convective storm occurred before the main storm and was localised over Kingston Park. The flow from the Kingston Park catchment is attenuated downstream (Figure 4.5). Once again, runoff from Kingston Park was dominant;
- Kingston Park and Red House flood hydrographs are flashy and have short lag times;
- Kingston Park and Red House had the highest flow for the main event (Figure 4.3) with the flood peak attenuating past Three Mile. This suggests runoff was greatest from these two urban catchments without much runoff occurring in between Red House and Three Mile. This could be a result of the golf course reducing runoff due to dry antecedent conditions;
- Rural flow was very low and can hardly be noticed on Figure 4.3, even though some rainfall occurred on the rural catchment. This suggests again the dry antecedent conditions may have prevented runoff.

4.1.3. High flow event – 21st January 2008

The 21st January event is different to the previous two events in that it is a result of a synoptic scale winter event. The high flows were a result of rainfall and snow. Soil antecedent conditions were wet as the catchment was nearly saturated due to rainfall over the previous few weeks (typical of winter). Rainfall was prolonged and was not as intense as the previous two events (Figure 4.7). Rainfall totals were not extreme (Table 4.1). Figure 4.6 displays the flood hydrograph for the four gauging stations for the event and rainfall is displayed on this in Figure 4.7. Figure 4.7 highlights that it stopped raining around 12.30pm on the 21/01/08. However, this is because it was snowing and the tipping bucket raingauge does not detect snowfall. This snowfall can be seen on the Met Office rainfall radar (Figure 4.8) which indicates that precipitation was occurring early afternoon on the 21st January 2008.

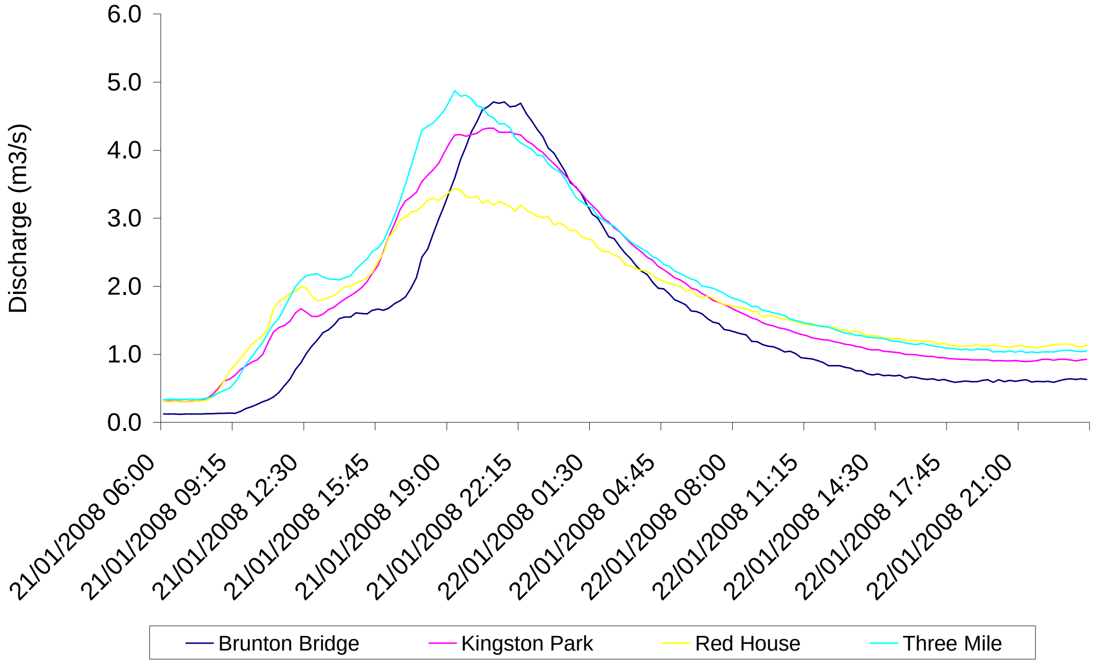

Figure 4.6: The 21st January 2008 storm hydrograph for the five upper Ouseburn gauging stations (EA Woolsington included which is upstream of Brunton Bridge).

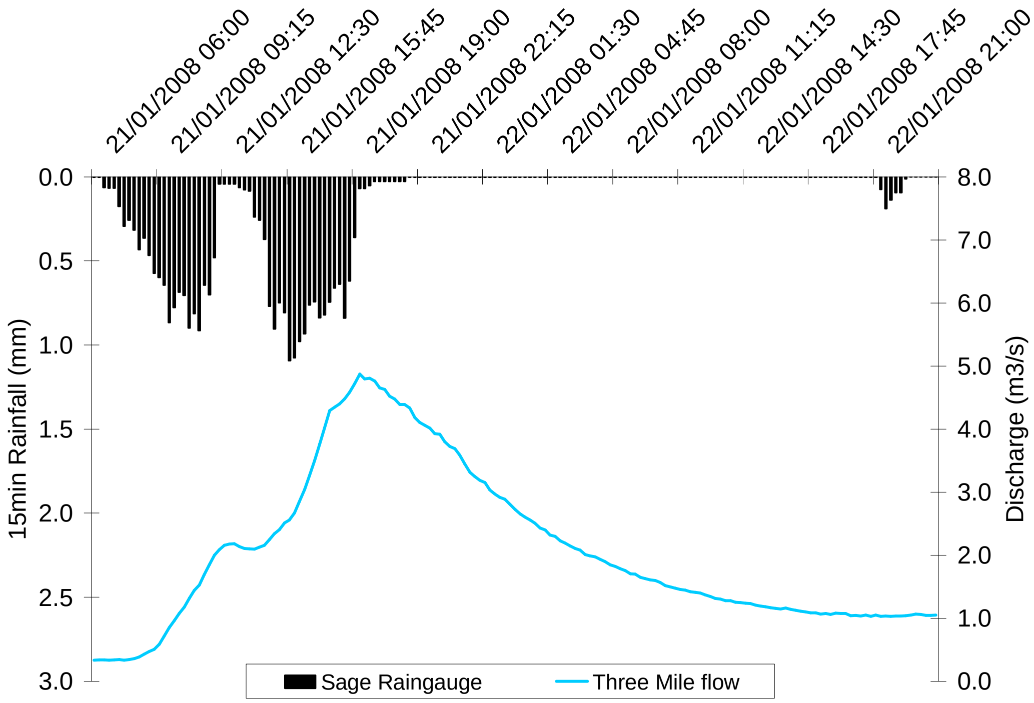

Figure 4.7: Rainfall and Three Mile bridge discharge for the 21st Jan 2008 storm event

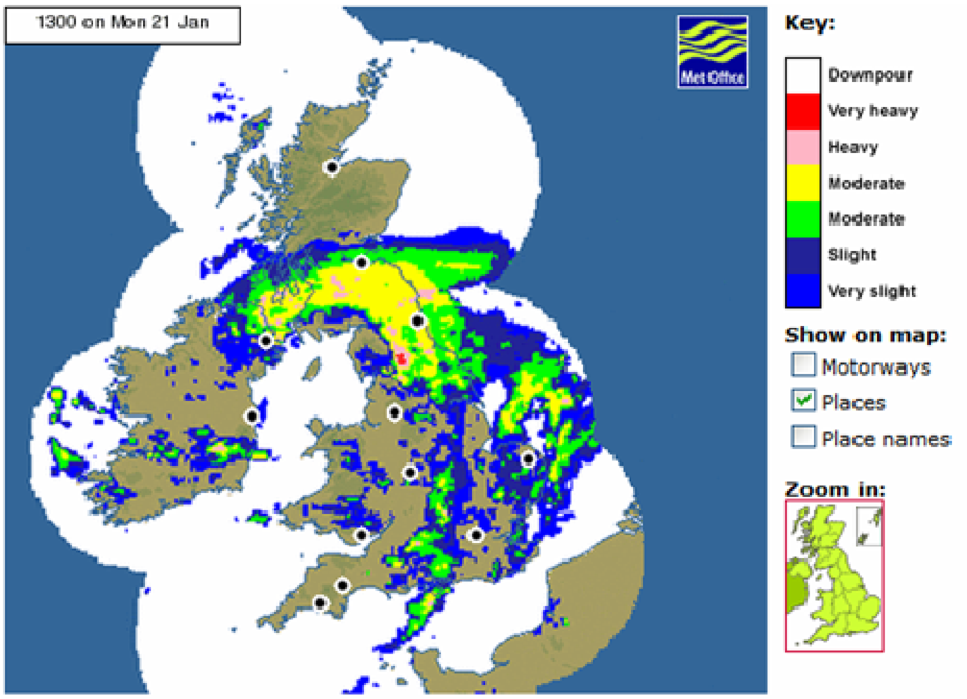

Figure 4.8: Rainfall radar (data from the Met Office) for the 21st January 2008 event.

Key findings from the 21st January 2008 event are:

- This event produced flows similar to that of the July 2007 event even though there was less precipitation and it was less intense. Increased runoff due to saturated antecedent conditions resulted in a high flow event;
- The rural catchment peak was much larger (with a steeper rising limb) than the previous two events. This highlights the increased runoff on the rural catchment due to a more saturated catchment compared to the previous two events (Figure 4.6);
- Compared to the previous two events, the rural peak lag time was shorter, but still occurs slightly after the downstream urban catchment peak. The peak of the rural catchment attenuates downstream on the back of the falling limb of the urban catchments;
- The urban catchment runoff on Kingston Park is still greater than the runoff of the Red House and Three Mile catchments (Figure 4.6). The peak is slightly delayed as it is being influenced by rural runoff;
- During winter events the antecedent conditions are more saturated. The rural flood peak is therefore larger and has a shorter lag time. If the rainfall was more intense (as well as being prolonged) over the rural catchment, then it is possible that the rural peak could coincide with the urban peak. The result would be a larger flood peak in urban areas;
- Finally runoff rates in the Kingston Park catchment are much larger than anywhere else in the catchment.

4.2. Storm runoff

The data in the previous section indicates that there is an increased runoff rate occurring from Kingston Park. It also highlights that in winter, runoff rates increase. Table 4.2 is a summary of ratio in runoff compared with rainfall expressed as a percentage. This was performed for the storm period. A 100% runoff would indicate all rainfall is passing out of the catchment as fast flow runoff.

Table 4.2: *A summary of ratio in runoff compared with rainfall expressed as a percentage for a summer and winter storm.*

% Runoff occurring in each catchment for a given storm		
	1st July 2007	21st January 2008
Brunton Bridge	29%	45%
Kingston Park	36%	41%
Red House Farm	29%	34%
Three Mile Bridge	22%	34%

Table 4.2 highlights that for the winter storm runoff rates are higher. The increase is considerably more for the rural catchment of Brunton Bridge. This indicates that the antecedent conditions in the rural catchment for winter storms are more saturated than for summer storms. Table 4.2 also confirms that the runoff rates at Kingston Park are higher than any other urban catchment.

5. Interaction of Cell I SUD with the Ouseburn

A level recorder was placed at the outlet of Cell I SUD (adjacent to the Ouseburn and located opposite to Red House Farm estate). The data is only available from January 2008. It can be assumed that the time of installation the level in the SUD was typical for winter and it is likely during summer that the SUD level will fall. The Ouseburn level at the time of installation was fairly low (as seen at the start of Figure 5.1).

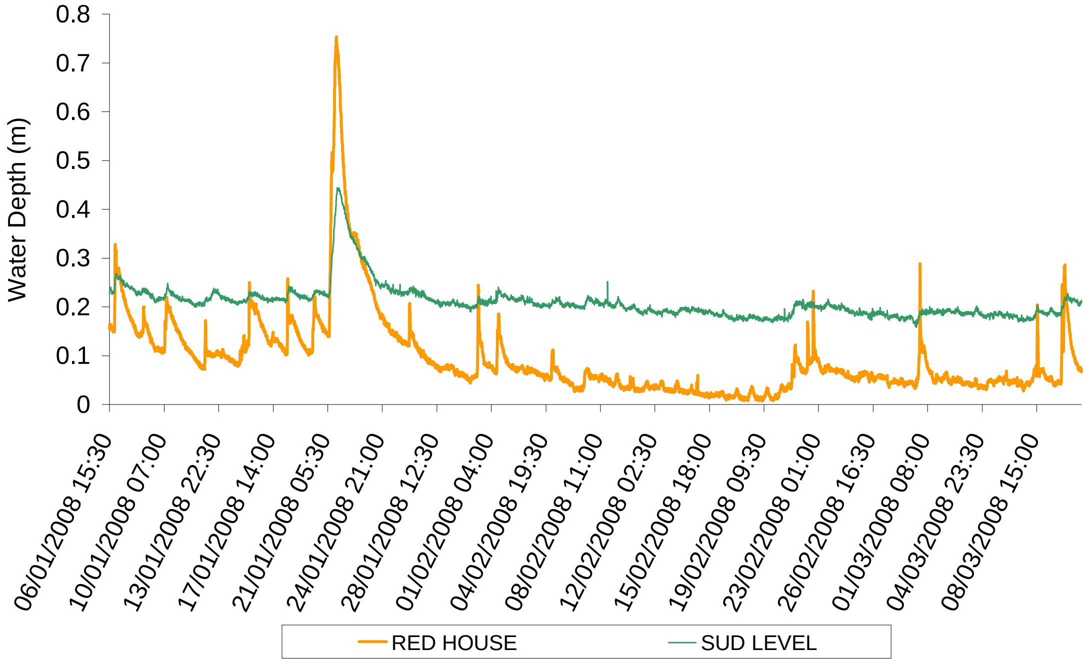

Figure 5.1 - A comparison of the depth of water at the Red House Farm gauging station and in Cell I SUD (next to Red House) for a two month period in winter.

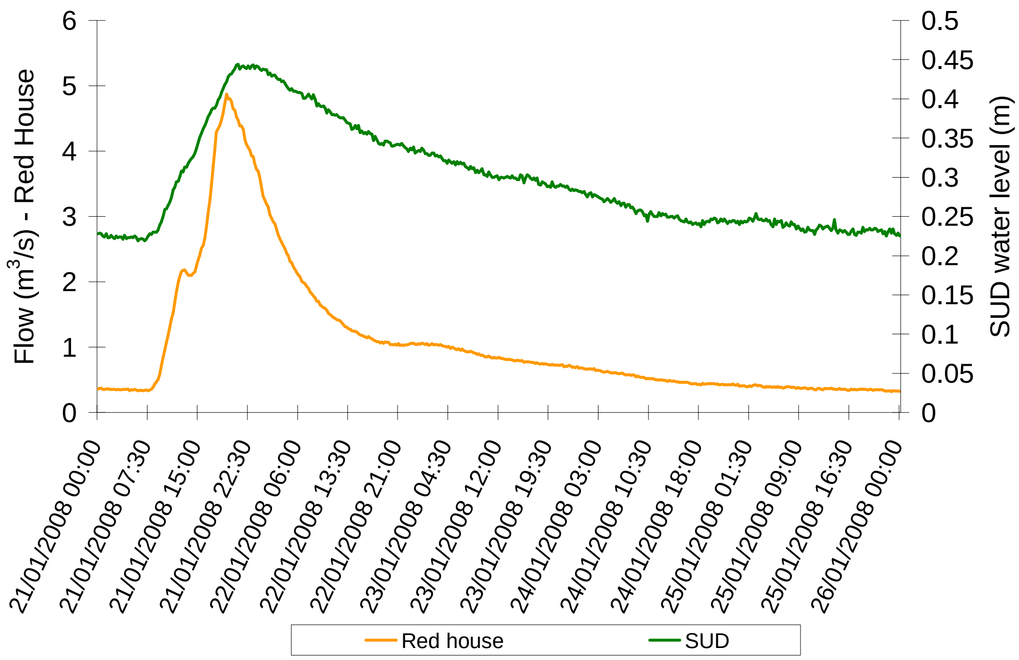

Figure 5.2 - A comparison of the flow at the Red House Farm gauging station and the depth at Cell I SUD (next to Red House) for the 21st January 2008 high flow event.

Figure 5.1 indicates that the SUD level does not respond to events where the stream level at Red House is less than 0.35m. The SUD only responded for one event in the three months it was logging and this was the event summarised in Section 4.1.3; the 21st January 2008 event. Figure 5.2 highlights how the SUD responds to the 21st January 2008 event but plotted against flow at Red House Farm. The rising limb of the SUD is slower than at Red House and peaks just one hour later than Red House. The SUD level rises over 20cm in depth. However, the key difference from the SUD and Red House is that the SUD falling limb is smoother and takes longer to reach background levels. This indicates the SUD is working correctly allowing small amounts of flow back to the Ouseburn over a long period of time. It must be stressed that more data is required from this SUD level recorder to fully understand how the SUD is working. Data is only present from one storm and more is needed.

6. Conclusions

The installation of three more raingauges and 4 level river gauges in the upper Ouseburn has improved the existing hydrometric network. The network has been logging for just under one year and the analysis of the data can be summarised into the following points:

- There has been no major localised rainfall event in the Ouseburn during the data logging period. Rainfall has been fairly uniform over the catchment;

- Runoff from the rural catchment for high flow events in summer is far lower than for urban catchments. The lag time of the peak for rural catchment is longer than for downstream urban catchments;

- The rural flood peak for the 1st July 2007 event is delayed due to lower runoff rates from agricultural land. This peak can be seen as a hump on the back of the falling limb of the urban catchments. This delayed peak prevents a higher flow levels further down stream;

- Runoff from the rural catchment for winter events is higher and the flow peak is much larger with a short lag time. The peak nearly coincides with the urban peaks. If intense prolonged rainfall did occur in winter then a flood event is more likely in urban areas;

- Runoff from Kingston Park is much greater than any other urban catchment system. As the Newcastle Great Park development increases it will be interesting to see the impacts of this land use change on the hydrology of the Ouseburn;

- It is unclear how the SUDs are interacting with the Ouseburn between Kingston Park and Red House with the current dataset. More data is needed along with SUD level monitoring.

- The upper Ouseburn catchment is undergoing major land use change (urban sprawl and transport infrastructure development). Continued data collection from the network will help to understand how land use change is affecting the hydrology of the catchment;

- Cell I SUD responds in a similar way to the high flow hydrograph at Red House (for 21st January 2008 event). However, the SUD falling limb is far smoother and takes longer to reach background levels. More data is required from the SUD to understand how it is working throughout a hydrological year and also how it responds to certain rainfall events (such as convective storms);

In conclusion, more data is required from the network to fully understand the hydrology in the upper Ouseburn. The short amount of data has not captured any serious flood events nor has it captured a large localised convective storm event, similar to that of June 2005. It is recommended that the hydrometry network is maintained as the data allow for a better understanding of the hydrology of the upper Ouseburn and to monitor the impact of the Newcastle Great Park development over the Ouseburn catchment hydrology.