ROSE ACRE, RIDGEDOWN & SNATCHUP

Redbourn

Technical Assessment Report to support Section 19 Flood Investigation

Project No: **0469**
Date: **October 2014**

Reviewed By: **Tom Butler**
Approved By: **Neil Harding**

NHTB Consultancy Ltd, Unit 1 St George's Works, Delamare Road, Cheshunt, Herts., EN8 9AP
01992 633271
www.nhtb.co.uk info@nhtb.co.uk

DOCUMENT CONTROL:

Project Number:	0469
Project Name:	0469 - Herts CC ERP-INV-05 Flood Investigations
Client:	Hertfordshire County Council

Revision	Originated	Checked	Approved
Draft	Name  Date 23-09-2014	Name  Date 23-09-2014	Name  Date 23-09-2014
Final	Name  Date 28-10-2014	Name  Date 28-10-2014	Name  Date 28-10-2014
1	Name  Date 05-12-2014	Name  Date 05-12-2014	Name  Date 05-12-2014
	Name Date	Name Date	Name Date
	Name Date	Name Date	Name Date

CONTENTS

1 INTRODUCTION

1.1 TERMS OF REFERENCE

This Technical Assessment Report to support Section 19 Flood Investigation was commissioned by Hertfordshire County Council (HCC) to investigate flooding at Rose Acre, Redbourn, Hertfordshire (the site). The report contains a summary of an investigation into the flooding to identify the areas affected, the flooding mechanism(s), the relevant Risk Management Authorities (RMAs) and it also includes potential mitigation measures.

1.2 THE INVESTIGATING CONSULTANT

The study was conducted by NHTB Consultancy Limited. The team consisted of a team of professional civil engineers with extensive drainage experience and personal knowledge of the Hertfordshire area.

1.3 FLOOD & WATER MANAGEMENT ACT 2010 - DUTY TO INVESTIGATE

The study described in this report was commissioned by Hertfordshire County Council (HCC) in their role as the Lead Local Flood Authority (LLFA) , as defined in the Flood & Water Management Act 2010. The Act requires, as specified in Section 19, that the LLFA investigate a flood when they are aware of the event and to the extent it considers appropriate and relevant. Specifically it must investigate which Risk Management Authorities (RMAs) have functions and whether they have exercised, or propose to exercise, those functions in response to the flood. Where an investigation under the Act is conducted the LLFA must publish the results of its investigation and inform relevant RMAs.

2 DETAILS OF THE SITE

2.1 SITE LOCATION

The area affected by flooding is shown in Figure 1 below. The area includes 8 residential properties in Rose Acre, 6 properties in Ridgedown and 3 in Snatchup.

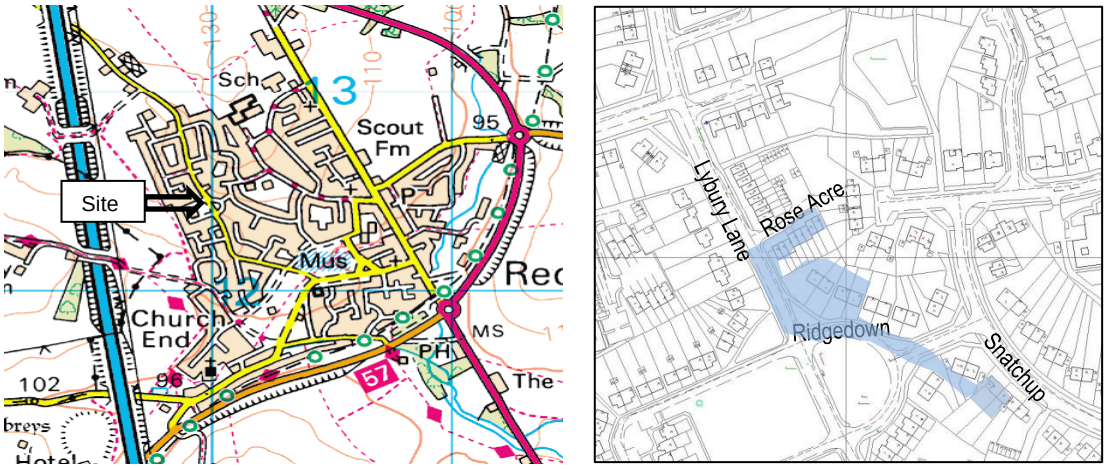


Figure 1: Site Location

2.2 SITE DESCRIPTION

The site is located to the west of Redbourn village and to the east of the M1. Lybury Lane starts as a single lane country road in Flamstead village and opens to allow two way traffic on the approach to Redbourn. At the point where Lybury Lane passes under the M1 the road starts to fall towards Redbourn at a fairly steady gradient.

The affected flooded area is a row of properties in Rose Acre, Ridgedown and Snatchup which are all affected by runoff from Lybury Lane.

3 FLOODING EVENT IMPACTS – 7 February 2014

3.1 INTRODUCTION

The storm event of 7 February 2014 occurred in the early hours of the morning. There had been a prolonged period of unusually wet weather in the weeks preceding the storm and the ground was saturated when the storm commenced. The rainfall was unable to infiltrate into the ground and significant surface water runoff resulted. The procedure adopted for this study to assess the impact of the flooding was to conduct interviews with those affected directly by the flooding and to identify and record the water flow paths and flooding mechanism.

3.2 FLOODING MECHANISM

3.2.1 Areas affected by flooding

There were three discreet areas affected by the flooding as illustrated in Figure 2 below. The first of these included a row of eight residential properties in Rose Acre, the second location was eight bungalows in Ridgedown and the third involved one property in Ridgedown and three properties in Snatchup.

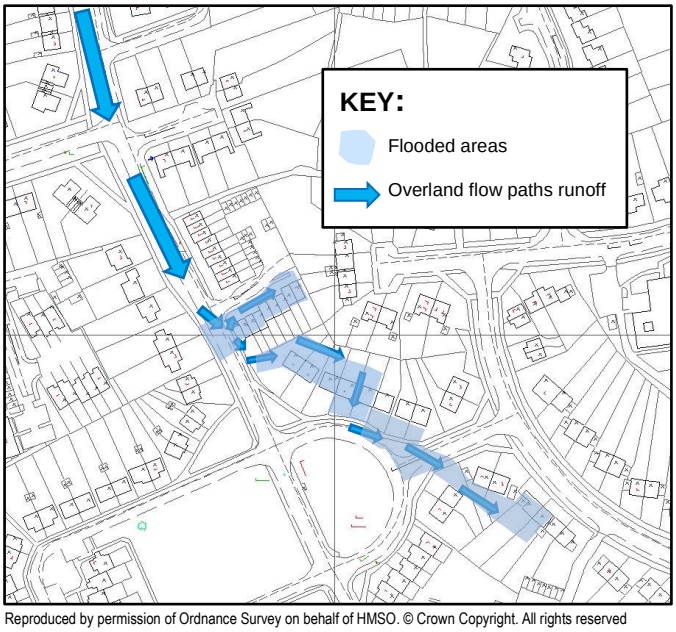


Figure 2: Flooding Mechanism – Overland Flow Paths

3.2.2 Overland Flow Paths

3.2.2.1 Lybury Lane

There were three distinct flooding areas as a result of runoff from Lybury Lane.

Area 1 - Rose Acre

The first area affected involved eight properties and was the result of runoff from Lybury Lane. Previous flood prevention works including a raised speed table and a channel drain across the entrance to Rose Acre, both caused more water towards the low point in Lybury Lane where the upstand on the kerbs are very low and water spilled over, also the quantity of water overwhelmed the speed table and directed flow towards the properties. Flood runoff entered the front gardens of properties in Rose Acre and was contained within the low lying area, the build-up of water then entered internally through front doors and air bricks.

Area 2 - Ridgedown

Overland flow from the low point in Lybury Lane is also the consequence of runoff into properties in Ridgedown. Flows ran from the front to the rear of No.1 through the rear of the properties and returned to the main road between No.7 and No.9. The flow path caused flooding to front and rear enclosed porch areas and contributed to the flooding in Snatchup (area 3). The flooding at Rose Acre is independent to this flow path and needs to be resolved separately.

Area 3 - Ridgedown & Snatchup

Ridgedown joins Lybury Lane very close to the low point in the road and acts as another relief mechanism for the overland flows conveying water towards the natural low point in Ridgedown (outside No.15 Ridgedown) The flow follows the lie of the land and flow routes via the rear of No. 6 Ridgedown and ponds immediately downstream of this point in the rear gardens of properties in Snatchup.

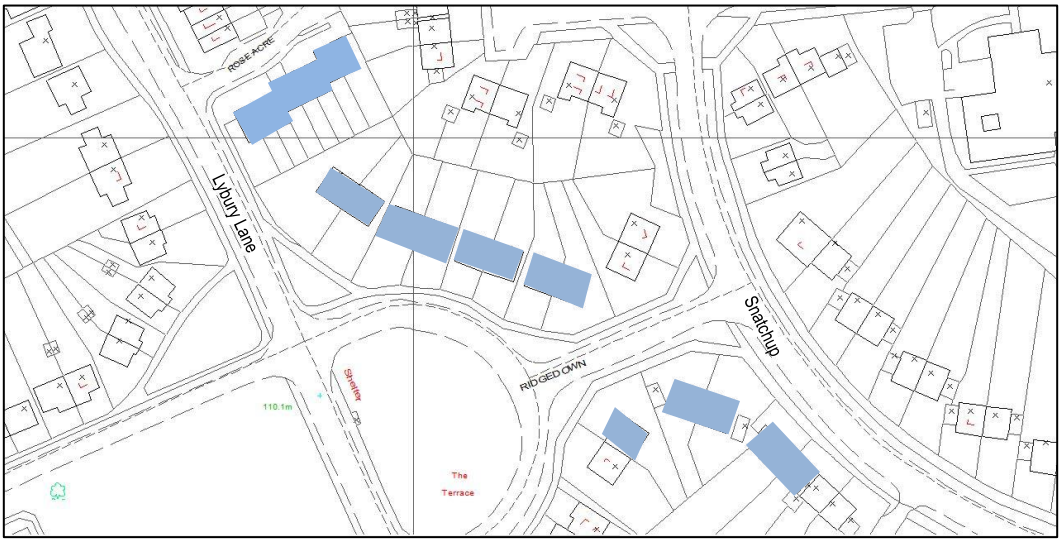


Figure 3: Flooded Properties

Property	Internal Flooding	External Flooding
Rose Acre	Yes (through front door)	Yes
Rose Acre	Yes (through side and front doors)	Yes
Rose Acre	Yes (through front door)	Yes
Rose Acre	Yes (through front door)	Yes
Rose Acre	Yes (through front door)	Yes
Rose Acre	Yes (through front door)	Yes
Rose Acre	Yes (through front door)	Yes
Rose Acre	Yes (through front door)	Yes
Ridgedown	Yes (through side door)	Yes
Ridgedown	Yes (through rear door)	Yes
Ridgedown	Yes (through rear door)	Yes
Ridgedown	Yes (through side door)	Yes
Ridgedown	Yes (through side door)	Yes
Ridgedown	No	Yes
Ridgedown	No	Yes
Ridgedown	No	Yes
Ridgedown	Unknown	Yes
Snatchup	Unknown	Yes
Snatchup	Yes (through rear door)	Yes
Snatchup	Yes (through rear door)	Yes

Table 1: Flood Event Impact Summary

3.3 RELEVANT STAKEHOLDER ENGAGEMENT

3.3.1 Local Residents and Businesses.

Occupants of each property in the areas affected by the flooding were interviewed as part of this study. Only one of the three properties in Snatchup were contacted and interviewed. The interviews were conducted in person with the resident/occupant wherever possible or over the telephone, by email or by the interviewee completing a questionnaire and returning it through the post. The information gathered from the interview process included the following:

- Details of the flooding mechanism; where the water came from and where it went (not in Snatchup)
- How the property was affected by the flooding including the depth of water inside and outside the property (not in Snatchup)
- The impact of the flooding; damages and other tangible and indirect effects (not in Snatchup)
- Photographic records
- Correspondence records

The interview information was recorded onto a standard questionnaire. Photographic images provided by some residents of the effects of the flooding are located in Appendix A. The properties affected by flooding are shown in Figure 3 above.

3.3.2 Hertfordshire County Council as Lead Local Flood Authority

Local residents in Rose Acre contacted the LLFA and this study has subsequently been commissioned.

3.3.3 Hertfordshire County Council as Highway Authority (Highway Drainage)

Residents of Rose Acre contacted Hertfordshire County Council in their capacity as the Highway Authority to arrange for the road drainage gullies in Lybury Lane to be cleaned. Many correspondence from the residents to the Highway Authority are located in Appendix A, evidence can be seen that the residents were highly concerned and were trying to ask for help up to 3 months prior to the flood. They personally witnessed the quantity of runoff flow and amount of debris washed down Lybury Lane suddenly increase and without maintenance to unblock the gullies felt their risk of flooding was getting greater.

3.3.4 Thames Water (Surface Water Sewers)

Thames Water have confirmed they do not have any surface water sewers in this vicinity of Redbourn. Residents from Rose Acre have confirmed the foul water sewers were in full operation and did not contribute to any flooding problems.

3.4 FLOOD DAMAGE COSTS

The nature of the flooding had different effects on each affected property; some experienced internal flooding of varying depth and consequence whilst others suffered external flooding only.

As part of the interview process with those affected by the flooding details were obtained of the financial implications of the flooding damage and these included those costs incurred by the resident/occupier and other costs that were the subject of an insurance settlement, or pending, insurance claim.

There was a significant range of damage costs disclosed during the interviews. A summary of the damages is shown in Table 2 below.

Location	Insurance Claim Costs	Personal Costs
Rose Acre	£15,000	
Rose Acre	£15,000	
Rose Acre	£6,500	
Rose Acre	£15,000	
Rose Acre	£20,000	
Rose Acre	£9,000	
Rose Acre	£14,296	
Rose Acre	Undisclosed	
Ridgedown		Minimal Value (£15.00)
Ridgedown		Undisclosed
Ridgedown		Undisclosed
Ridgedown		Undisclosed
Ridgedown		Undisclosed
Ridgedown		Undisclosed
Ridgedown		Undisclosed
Ridgedown		Undisclosed
Ridgedown		Undisclosed
Snatchup		Undisclosed
Snatchup	£70,000	
Snatchup	£25,000 (Assumed)	

Table 2: Flood Damages - Costs Summary

The damage caused by the flooding to eight properties in Ridgedown was minimal, only just entering inside the front and rear porches. The residents chose not to submit insurance claims and instead paid for the replacement of small items of furniture and carpeting at their own expense. Insurance claims were made from eight properties in Rose Acre and at least two properties in Snatchup, where the flooding damage was much more extensive and shown by the insurance claim costs.

4 HISTORICAL FLOOD EVENTS

4.1 INTRODUCTION

During the flood survey interviews, several of the residents of Rose Acre referred to one other significant flooding event that affected the same group of residential properties. The flooding occurred in December 2007 during the construction phase of the M1 widening scheme, we understand the flooding was due to temporary inadequate drainage retention during the construction stage and now adequate balancing ponds are in place. The cause of the flooding was very similar to 7 February 2014 where surface water was routed by overland flow down Lybury Lane into the front of the properties in Rose Acre.

Following the initial flood the Highways Authority immediately responded and installed a raised speed table at the entrance to Rose Acre to provide a barrier and re-direct flows further along Lybury Lane. The low point in Lybury Lane is

located between Rose Acre and Ridgedown where flows now pond, levels exceed the low kerbs and flows are directed towards the properties.

4.2 FLOOD HISTORY

The flooding in December 2007 occurred during the construction of the M1 widening scheme and it is believed there was inadequate temporary drainage in place. All residents agreed this flood was less severe than on 7 February 2014 but did cause internal flooding to all properties in Rose Acre. The flooding also affected the garage of one property in Snatchup and resulted in internal flooding of several centimetres.

Following the floods in December 2007 Hertfordshire County Council agreed to install a raised speed table and concrete channel drain on the entrance to Rose Acre to redirect flows further along Lybury Lane. All residents were very pleased with the works and were hoping the risk to further flooding had been minimised. In December 2013 the residents had growing concerns to the quantity of debris and water flowing down Lybury Lane and the level to which this water was reaching on the raised speed table.

Unfortunately no remedial works were undertaken prior to 7 February 2014, the properties of Rose Acre and also properties to the rear in Ridgedown and Snatchup suffered internal flooding.

5 CATCHMENT CHARACTERISTICS & EXISTING SURFACE WATER DRAINAGE INFRASTRUCTURE

5.1 INTRODUCTION

The catchment that drains to the area where flooding occurred measures approximately 20.4ha. The catchment is shown in Figure 4 below and consists of three principal areas:

Farmland East Side
Farmland West Side
Residental

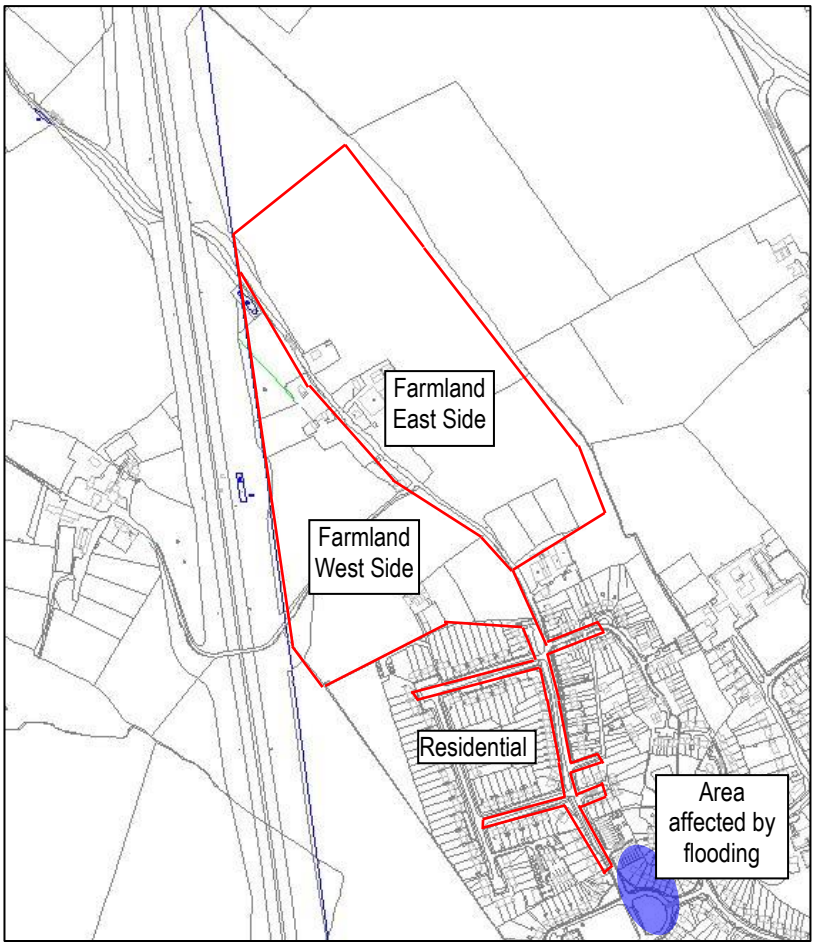


Figure 4: - Catchment Boundary

5.2 TOPOGRAPHY & GEOLOGY

5.2.1 The catchment is relatively steep sloping from a high point to the north of approximately 123m elevation to the lowest point in Rose Acre where the initial flooding occurs, at an elevation of approximately 110m. Snatchup is located slightly more southern at a lower elevation of 108m.
The northern section of Lybury Lane lies in a valley between the M1 motorway and a tree boundary line at the rear of Redbourn Recreation Centre. Lybury Lane is surrounded by arable farmland and is prone to surface water runoff from the fields to the road that falls south towards residential properties.

Beyond the junction with Hill Top, Lybury Lane forms a residential street that continues to fall in a southern direction. The carriageway is prone to direct overland surface flows with all houses in Lybury Lane positioned slightly higher than the carriageway level and therefore not affected by any flooding issues.

5.2.2 A topographical survey was conducted on the principal elements of the catchment including those areas where major sources of surface water runoff resulted in overland flow and where flooding was experienced. This survey was conducted by NHTB Consultancy and utilised precision Total Station survey techniques supplemented by GPS measurements where appropriate. The survey data was

used to identify and measure overland flow paths that were used subsequently in the hydrological analyses (refer to Chapter 6 below) and surface depressions where surface water runoff collected, either causing flooding of properties or where runoff was held before the locations affected by flooding.

5.2.3 The geology of the catchment is a combination of Glacial Sand and Gravel deposits and Chalk as shown in Figure 5 below. This would imply that the catchment is relatively free draining with high permeability. This issue is explored in Section 6.2.2 below where it is postulated, based on experience of surface water runoff under extreme conditions in other parts of Hertfordshire, that runoff is influenced significantly by factors other than soil type.

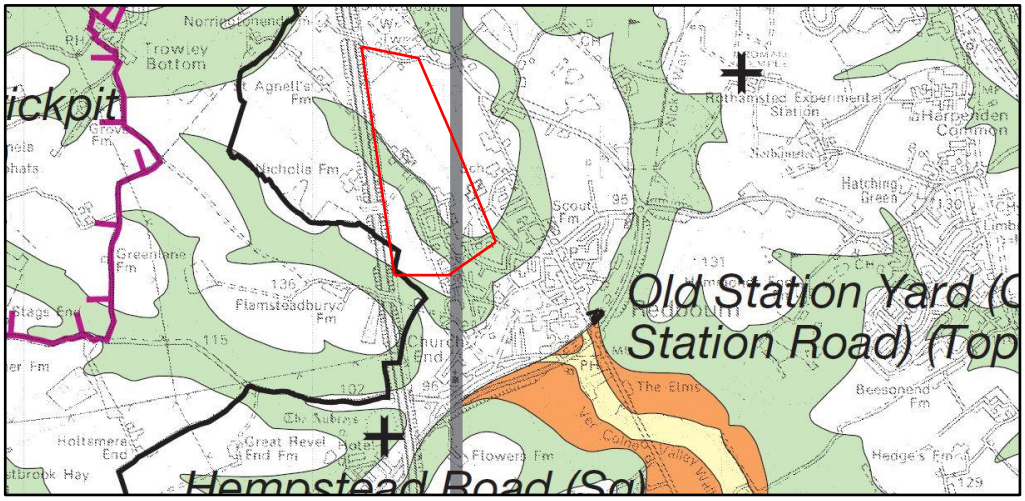


Figure 5: - Geology

Key:
- Catchment boundary
- Chalk bedrock
- River terrace deposits
- Glacial sand and gravel deposits

5.3 LAND USE AND SURFACE WATER DRAINAGE ARRANGEMENTS

There is only one principal surface water drainage system which is the responsibility of and maintained by the Hertfordshire Highway Authority.

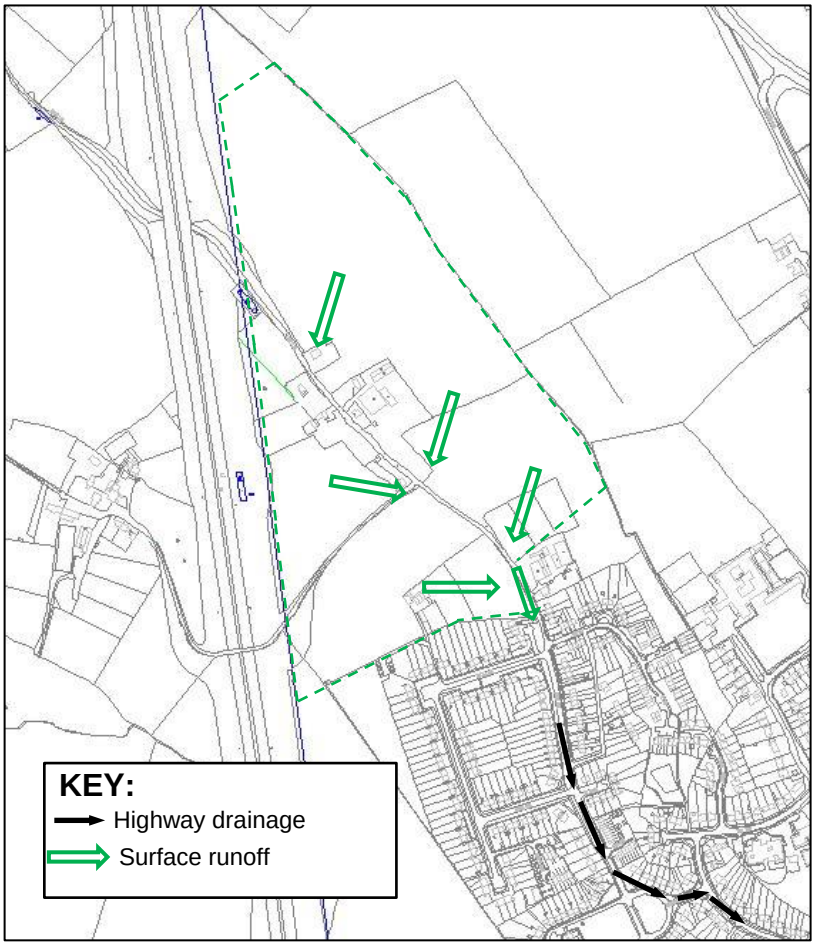


Figure 6.1: - Surface Water Drainage Systems

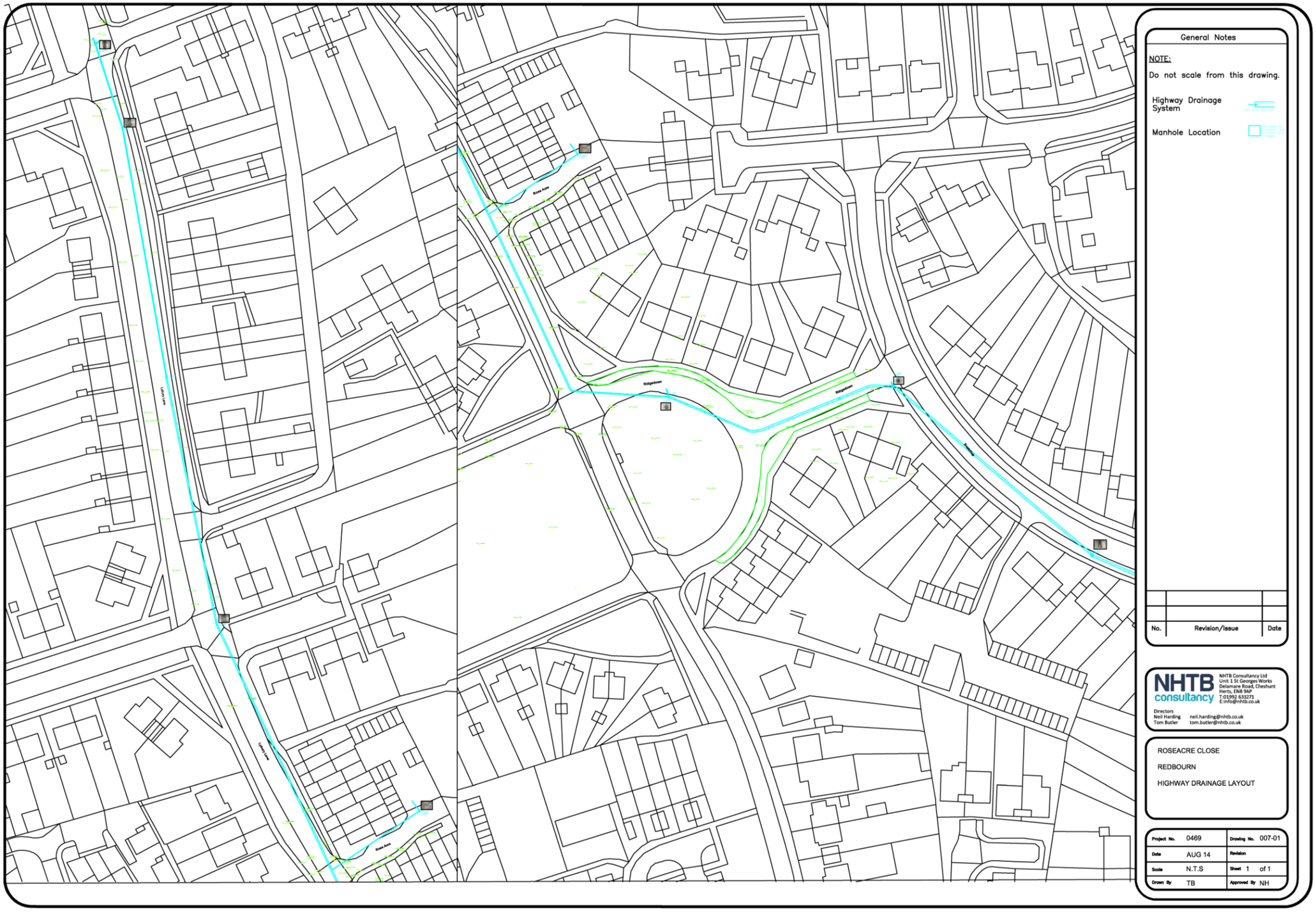


Figure 6.2: Highway Drainage System

5.3.1 Highway Drainage (Hertfordshire County Council as the Highway Authority)

There is a highway drainage system serving the residential section of Lybury Lane. A survey of the system was conducted as part of this study. There are regularly spaced road gullies along Lybury Lane with an initial double gully adjacent to the west farm field designed to capture field runoff flows close to the source. In response to the December 2007 floods a road hump and concrete channel drain were installed to redirect the flow of water beyond the junction of Rose Acre. The concrete channel is not designed to capture the flow and discharge into the existing highway system, only to encourage the water to flow towards the low spot in Lybury Lane. The location and principal details of the highway drainage system is shown in Figure 6.2 above.

During the survey of the highway drainage all road gullies in Lybury Lane were clear and appeared to be operational. There are manhole chambers along the line of the highway drain and these were also inspected and found to be clear with the exception of the manhole chamber in Rose Acre, at the entrance to the garages, which was partially blocked with silt.

Photographic evidence taken during the time of the storm shows this is not always the case and become easily blocked when runoff flows wash fine silt and debris off the fields into the carriageway. Residents from Rose Acre carefully monitor the condition of the gullies and regularly keep the surfaces clear to help keep in maximum operating performance. The highway drain is believed to follow the topography of the land along Ridgedown, Snatchup and beyond, eventually discharging into a main river on the opposite side to ‘The Common’.

During unsaturated conditions, surface water from the west and east farmland immediately adjacent to Lybury Lane should infiltrate directly into the permeable soil, once the ground becomes saturated (as experienced during the 7 February 2014 floods) the water will follow the ground profile and run off directly onto the road and rely on the highway gullies to intercept the flow. Once the overland flow commences the gullies begin to block with fine silt and debris causing flow to continue along Lybury Lane. Runoff calculations will determine the quantity of flows and assumptions will be made to the condition and capacity of the highway drainage system.

5.3.2 Surface water sewerage (Thames Water)

There are no Thames Water surface water sewers in this local vicinity.

5.3.3 Land Drainage

5.3.3.1 Field Drainage (east and west side of Lybury Lane)

We are unaware of any land drainage in the arable fields to the east or west of Lybury Lane. There does appear to be a slight bund on the western field preventing direct runoff onto the carriageway, there does not appear to be a positive outfall connection and we assume flows are intended to infiltrate into the soil. A trench has now been cut into the small bund opposite No.96 Lybury Lane which provides a free outfall onto the road for all runoff from the western field.

There is also evidence of runoff trenches through the tree line on the eastern field, with distinct valleys to direct flow towards Lybury Lane.

5.3.3.2 Ordinary watercourses

There are no ordinary watercourse in the local vicinity.

5.3.3.3 Main Rivers (Environment Agency)

The only main river is located on the opposite side to 'The Common'. We believe all highway drainage discharges towards the river but the river has no hydraulic impact to the flooding in Rose Acre.

6 HYDROLOGICAL ASSESSMENT

6.1 INTRODUCTION

As part of this investigation, an assessment was made of the rainfall conditions that precipitated the flooding. The assessment took into consideration the conditions prior to the flooding including the catchment conditions and antecedent rainfall in the period leading up to the storm that caused the flooding. Other contributory factors that may have influenced the flood event were also investigated and are described below. The investigation sought to confirm the flooding mechanism and to quantify the various factors that combined to cause the flooding putting each into relative perspective and scale with the others. The second part of this chapter describes the results of a hydrologic assessment that examined how the catchment and components of the highway drainage systems would respond to a range of statistical design storms under a range of antecedent conditions. The final part of this chapter makes reference to other recent flood risk assessments that have been conducted and how they compare to this investigation.

6.2 ASSESSMENT OF 7 FEBRUARY 2014 STORM EVENT

6.2.1 Rainfall data

Details of rainfall recorded at three permanent rain gauge sites maintained by the Environment Agency were obtained by the LLFA for this investigation. The gauges were located at the following sites shown geographically in Figure 7 below:

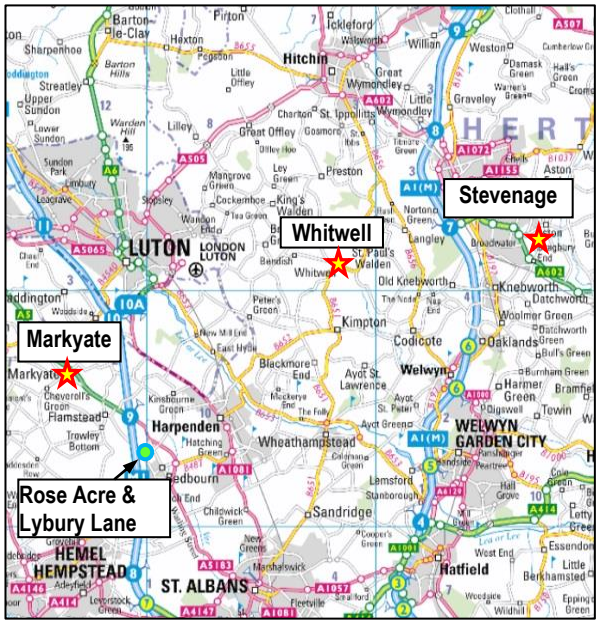


Figure 7: Rain gauge locations

The measurements of rainfall were recorded as a total depth of rainfall over each successive 15 minute interval.

A brief summary of the rain recorded by the rain gauges is presented below in Table 3.

	Stevenage TBR	Whitwell STW TBR	Markyate STW TBR
Date/time	**Depth of Rain (mm)**	**Depth of Rain (mm)**	**Depth of Rain (mm)**
07/02/2014 00:15:00	0	0.1	0.2
07/02/2014 00:30:00	0	0.3	0.8
07/02/2014 00:45:00	0.2	0.7	1
07/02/2014 01:00:00	0.2	0.5	1
07/02/2014 01:15:00	0.2	0.5	0.4
07/02/2014 01:30:00	0.4	0.6	0.4
07/02/2014 01:45:00	0.4	0.3	0.2
07/02/2014 02:00:00	0.2	0.6	0.4
07/02/2014 02:15:00	0.4	1.3	1
07/02/2014 02:30:00	0.8	1.3	1.2
07/02/2014 02:45:00	1.2	1.9	1
07/02/2014 03:00:00	1.4	1.9	2.2
07/02/2014 03:15:00	2	1.9	1.6
07/02/2014 03:30:00	1.4	1.7	1.2
07/02/2014 03:45:00	3	1.5	1.2
07/02/2014 04:00:00	3.2	1.6	0.8
07/02/2014 04:15:00	1.8	0.9	0.8
07/02/2014 04:30:00	1.2	0.5	0.6
07/02/2014 04:45:00	0.8	0.7	0.4
07/02/2014 05:00:00	0.4	0.1	0
07/02/2014 05:15:00	0.4	0.1	0.2
	19.6mm	19mm	16.6mm

Table 3: Rainfall Summary (7 February 2014)

From examination of the data above the following details are evident:

(i) The storm commenced just after midnight on 6 February and continued for approximately 5 hours

(ii) 16.6mm of rain was recorded at the Markyate rain gauge (the nearest to Redbourn) located approximately 6km to the northwest of Rose Acre, Redbourn in the Markyate sewage treatment works.

(iii) The storm was reasonably consistent in character as it moved across the catchment from west to east (Markyate to Stevenage) with approximately 15% variation in total depth of rainfall recorded between the three gauges. The maximum depth of rainfall recorded by the rain gauges was at Stevenage.

(iv) The rainfall intensity peaked at 2.2mm in the fifteen minute time period from 03:00am. This equates to an average intensity of 8.8mm/hr. The average intensity for the storm event as a whole was 3.6mm/hr (16.4mm over 4:30 hours)

The depth of rainfall recorded in Markyate does not represent rainfall of unusually high intensity nor significant quantity. As an illustration the data in Table 4 below shows the average equivalent depths and intensities for design storms of a similar

duration and increasing severity compared to the event of 7 February 2014. The rainfall characteristics compare very favourably with those of a theoretical storm of 1 in 1 year return probability.

Storm Return Period	Storm Duration	Average Rainfall Intensity	Rainfall Depth
7 February 2014	**270 mins**	**3.6 mm/hr**	**16.4mm**
1 in 1 year	270 mins	4.3 mm/hr	19.35mm
1 in 5 years	270 mins	6.6 mm/hr	29.7mm
1 in 10 years	270 mins	7.7 mm/hr	34.7mm
1 in 50 years	270 mins	11.0 mm/hr	49.5mm
1 in 100 years	270 mins	12.8 mm/hr	57.6mm

Table 4: Illustrative Design Rainfall Characteristics

Under normal conditions, a storm of 1 in 1 year return period would not be expected to create flooding conditions as witnessed on 7 February 2014 in Rose Acre. Other contributory factors to the flooding are discussed below.

6.2.2 Catchment Antecedent Conditions

The period leading up to the flooding event was unusually wet and the ground was reported by the local residents as being saturated in the arable fields to the east and west of Lybury Lane. An assessment of the rainfall recorded over the preceding 28 days is reported in Table 5 below.

The data in Table 5 below shows that there was almost 109mm of rain over the 26 days prior to the flooding event on 7 February 2014. This is considerably greater than the average that would be expected. The standard average annual rainfall (SAAR) for this part of the UK is 600mm which equates to a monthly average (January) of 60mm. The average rainfall data for January is shown in Figure 8 below. The amount recorded is typically 80% greater than the average and, more importantly there was 23.8 mm recorded in the 48 hours before the flood event. This rainfall would have resulted in the soil being saturated and the removal of any soil moisture deficit (SMD). Despite the basic soil type for this area being based on glacial deposits of sands and gravels plus chalk the prolonged period of rainfall in the weeks leading up to the storm event means the soil structure would have been unable to absorb the intense rainfall that occurred on 7 February 2014. These two factors in combination would have created conditions conducive to a very high percentage runoff that in turn would have resulted in most of the rainfall that fell converting into surface water runoff. The typical percentage runoff that would be expected from a permeable surface from a theoretical design storm is approximately 35% (wetted). In comparison, the runoff from an impervious surface would be in the range of 95% (wetted).

	Stevenage TBR	Whitwell STW TBR	Markyate STW TBR
Date/time	**Depth of Rain (mm)**	**Depth of Rain (mm)**	**Depth of Rain (mm)**
11/01/2014	1	0.8	1.4
12/01/2014	2.4	2.9	3
13/01/2014	4.2	2.7	3.6
14/01/2014	1.4	1.8	2
15/01/2014	3.4	3.3	4
16/01/2014	8.2	10	4.6
17/01/2014	1	1.4	2
18/01/2014	2.4	1.7	1.2
19/01/2014	0.4	0.2	1.4
20/01/2014	0	0	0.2
21/01/2014	0.2	0.7	0.2
22/01/2014	6.2	8.2	6.4
23/01/2014	3.4	3.2	2.8
24/01/2014	4.4	5	5.6
25/01/2014	3.4	2.8	3.2
26/01/2014	5.8	7	8.2
27/01/2014	0.8	0.6	1.6
28/01/2014	2.4	3	1.4
29/01/2014	7.6	8.7	10
30/01/2014	4.2	3.3	2.6
31/01/2014	8.2	8.3	10
01/02/2014	5.8	7.4	6
02/02/2014	0	0	0
03/02/2014	0	0	0
04/02/2014	1.6	2.3	3.4
05/02/2014	8.2	9	13.8
06/02/2014	8.6	9.5	10
	100.9mm	**110.6mm**	**108.6mm**

Table 5: Antecedent Rainfall Summary

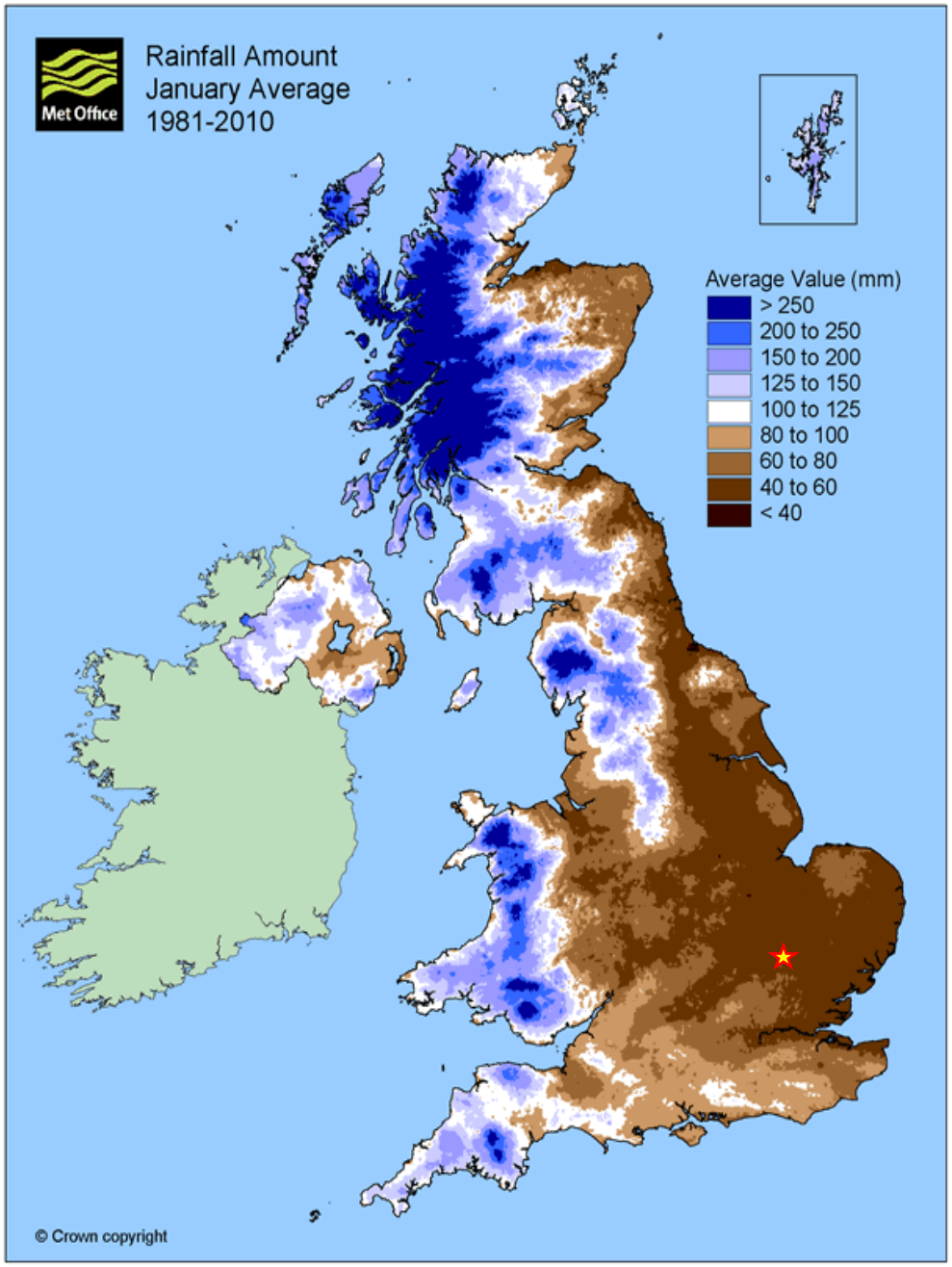


Figure 8: Average Monthly Rainfall Depth for January

6.2.3 Runoff assessment

A hydrological assessment was undertaken of the 7 February 2014 storm event to investigate how the catchment runoff converted into overland flows from the 3 principal catchment areas (refer to Figure 4), the residential street, farm land to the east and west of Lybury Lane. The analyses are included in Appendix B. The analyses included certain assumptions as summarised below:

Hydrological analysis assumptions:

(i) The catchment was saturated before and during the storm event
(ii) The highway drainage system provided negligible capacity and impact on drainage of runoff from Lybury Lane on the basis of the images taken shortly after the storm event and which show gullies full of silt and debris
(iii) The rainfall intensity profile during the storm was assumed to be an equivalent average intensity
(iv) Lybury Lane has an average gradient of approximately 1 in 60.

6.2.4 Assessment of Existing Drainage Infrastructure

Highway Drainage

Evidence from pictures taken by residents during the storm (see Appendix A) show the gullies were full with silt and debris and non-operational at the time of the storm in February 2014. The silt and debris is a result of the field runoff during the storm. The gullies and all manholes that form part of the highway drainage system in Lybury Lane, Ridgedown and Snatchup were clear and operational during the time of the survey conducted in October 2014 as part of this investigation.

Photograph courtesy of resident of Rose Acre

Figure 9: Blocked Gullies in Lybury Lane
(Image taken following the storm event in February 2014)

Normally highway drainage is designed for storm conditions that are less severe than the exceptional weather that occurred over the winter of 2013-14. The highway drainage system would not have been able to accommodate all of the surface water runoff from the extreme conditions experienced, even if each component part was operating to its optimum performance. As an illustration, the theoretical capacity of the highway drainage system, based on the different pipes sizes and gradients along Lybury Lane, Ridgedown and Snatchup (as indicated in Figure 6.2) are summarised in Table 6 below.

Location	Pipe Size	Gradient	Theoretical Capacity (l/s)
Lybury Lane (upper) MH01 - MH02	300mm dia.	1 in 18	262
Lybury Lane (lower) MH04-MH06	450mm dia.	1 in 75	370
Ridgedown MH06 - MH07	375mm dia.	1 in 88	215
Snatchup MH07 - MH08	525mm dia.	1 in 122	433
Peak runoff from fields (Feb 2014 event)			**102**

Table 6: Summary of Theoretical Pipe Capacities and Storm Runoff for the February 2014 Storm

The figures in Table 6 above indicate that, theoretically, there is sufficient capacity within the highway drainage system pipework to convey all of the surface water runoff. In reality this is not likely because the water will be unable to be collected from the road surface and conveyed into the pipework below ground due to the limiting capacity of the existing road gullies. The theoretical capacity figures shown in the table assume that there is an unrestricted passage of flow in the highway drain along Snatchup. If there are hydraulic restrictions the capacity in Ridgedown and the section of Snatchup (MH07 to MH08) could be reduced potentially to the extent that it could result in flooding. The highway drain in Snatchup should be investigated along its full length as part of any future development of potential mitigation measures.

6.3 IMPACT OF EXTREME STORM EVENTS

6.3.1 Rainfall criteria and catchment antecedent conditions

A simplified method of hydrological assessment was conducted as part of this investigation to ascertain the impact of design storms of increasing severity and the likely flooding and consequential damages that they would induce. In making the assessment, certain assumptions and simplifications were made as summarised below:

(i) The assessment was conducted on the basis of deriving the total volume of surface water runoff within separate principal sectors of the catchment, removing volumes that would be accommodated in any large surface depressions then calculation of the depth of flow in principal overland flow paths to derive depths of flow and the properties that would be expected to flood. Flood damages were calculated on the basis of typical higher-end insurance and privately funded repair costs obtained from the flooding interview data

(ii) Rainfall data and runoff volumes were derived from standard data profiles and processed by the 'FLOOD2' analysis software (Copyright Hertsmere Borough Council)

(iii) The duration of each design storm was set at 270 minutes to be equivalent to the flood event of 7 February 2014
(iv) The catchment was saturated prior to the storm and all rainfall was converted into surface water runoff
(v) The calculations assume that no runoff enters the highway drainage system.

6.3.2 Predicted flooding impact

Details of the hydrological analyses are contained in Appendix C. A general summary is provided below.

Four different scenarios were analysed using two design storm return periods; 1 in 10 year event and 1 in 100 year event. Each was analysed with a dry and a wet catchment before the storm. The following summary Table 7 shows the calculated depths of flow along Lybury Lane, which are comparable to supporting evidence from residents. The main flooding issue results from ponding in localised low lying areas of Lybury Lane and Ridgedown where the depth of standing water exceeds the kerb level and flows directly towards the properties. Although the depths stated in Table 7 below represent a true comparison to the flow depths at a steady 1 in 60 gradient, the flooding originates from low lying areas where the depth will be much greater. In order to obtain precise depths throughout the catchment detailed hydraulic analysis assessments will be required.

Storm	**Depth of flow on Lybury Lane**
1 in 10 year dry catchment	52mm
1 in 10 year wet catchment	56mm
1 in 100 year dry catchment	72mm
1 in 100 year wet catchment	78mm
7 February 2014	**40mm**

Table 7: Summary of Design Storm Hydrological Analyses

The figures above in Table 7 make no allowance for any water being collected from the road surface and discharged into the highway drainage system. These are the conditions that existed in the February 2014 event. If adequate gullies or other proprietary collection features are introduced to collect all surface water from the road surface there should be no surface water flow on the road surface for any of the storms considered in the analyses. Recommended road surface drainage details are described in sections 7 and 8 below.

6.3.3 Predicted Damage Costs

The predicted depths of flood water for the 1 in 10 year and 1 in 100 year design storm conditions assume the surface flow conditions shown above in Table 7 as a consequence of there being inadequate road surface drainage arrangements to convey water into the pipes belowground. The flow depths are all greater than that of the 7 February 2014 event and as a result it is to be expected that there would be a greater likelihood of more water entering inside properties. In the February 2014 event flooding entered eight properties in Rose Acre, five properties in Ridgedown and two properties in Snatchup. One of the two properties in Snatchup had considerable damage and residents are only just moving back into the

property seven months later. There were five other properties in Ridgedown which are positioned slightly higher and experienced external flooding only. For more extreme storm conditions it is projected that the internal flooding would be deeper and those properties only experiencing external flooding could be exposed to internal flooding problems.

In Rose Acre the average value of insurance claims made by those for which data is available is £13,500. This value is reasonably consistent with the average value of claims (£10,000) made for smaller residential properties where internal flooding greater than 25mm has occurred throughout the ground floor affecting typically the kitchen, lounge and dining room. It is typical for the value of damage costs to rise only marginally with increase in flood depths above 25-50mm as most furniture, kitchen floor units, carpets and plaster are generally affected by the initial shallow depth of flooding and no further damage (replacement costs) is incurred by an increase in depth of water. There may be some exceptions to this general presumption however if high value electrical goods (televisions, audio equipment etc.) are affected as the flood water increases in depth. On this basis the damage costs for a 1 in 100 year event are considered to be at least 10% greater than those for a 1 in 10 year event.

Properties in Ridgedown experienced minor flooding on 7 February 2014, we assume due to the property risk that depths could increase during 1 in 10 and 1 in 100 year event leading to much greater internal flooding. For cost calculation purposes we have assumed an average claim value similar to that in Rose Acre during the higher storm return periods.

Due to low level ponding one property in Snatchup experienced severe internal flooding up to 300mm deep causing approximately £70,000 damages. A flood depth of 300mm will have caused substantially more damage to the property and items within the home, which is reflected in the damage cost. An adjacent property in Snatchup also stated a flood depth of approximately 100mm, for estimating purposes a damage value of £25,000 has been assumed.

In consideration of these factors we consider that the typical costs of damages for each residential property are as shown below in Table 8.

Property: Flood Level (mm)	**Predicted Damage Costs**	
	1 in 10 years	**1 in 100 years**
Ridgedown: 0 – 25 mm	£13,500 / property	£14,850 / property
Rose Acre: 25 – 50 mm	£13,500 / property	£14,850 / property
Snatchup: 300mm	£70,000 / property	£77,000 / property

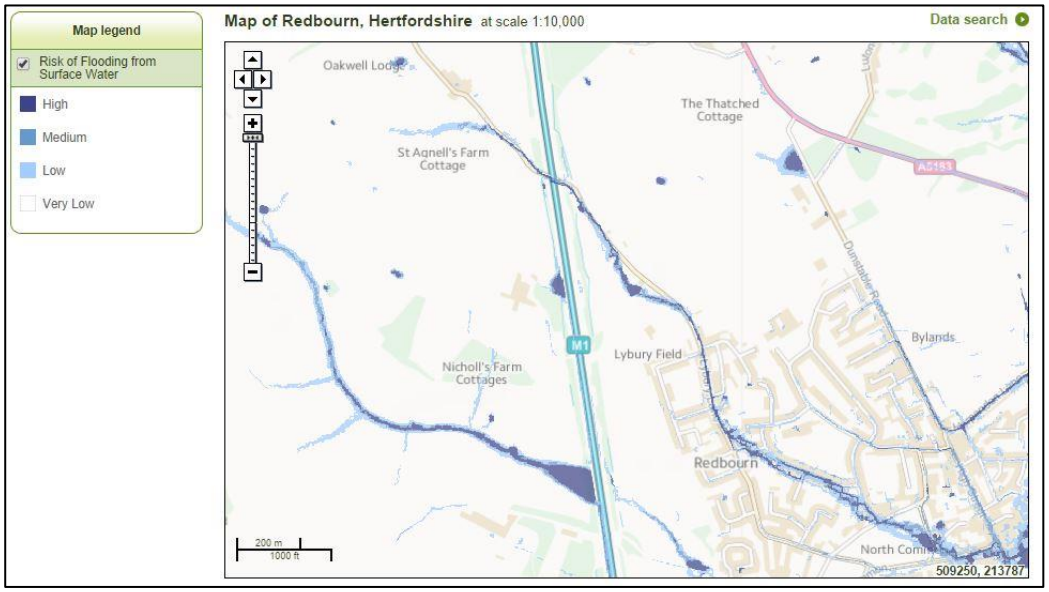
Table 8: Predicted flood damages

6.4 FLOOD RISK ASSESSMENTS

6.4.1 Environment Agency Surface Water Maps

Results of the analysis undertaken by the Environment Agency are illustrated below in Figure 10. They show a reasonable correlation with the surface water runoff witnessed by local residents on 7 February 2014. The map shows a true comparison of the witnessed flow paths along Lybury lane, turning into Ridgedown

and towards the rear of properties in Snatchup. The area of Rose Acre, Ridgedown and Snatchup are all classified as small pockets of high flooding risk.

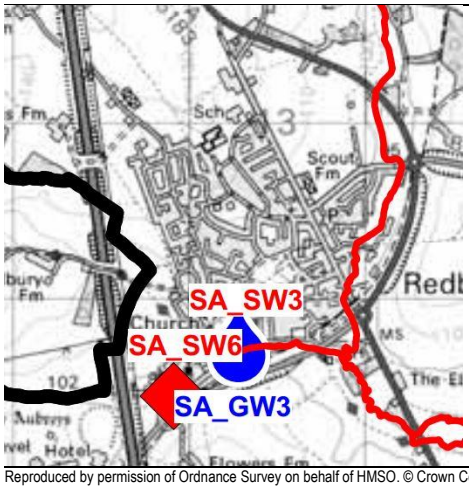


Environment Agency copyright and database rights 2014, Ordnance Survey Crown copyright

Figure 10: Environment Agency Surface Water Maps

6.4.2 St Albans District Council SFRA

A Strategic Flood Risk Assessment was produced in 2007 for the administrative catchment of St Albans District Council. The SFRA included a record of historic surface water flooding. There was no record in the SFRA of any flooding in Rose Acre or surrounding roads as shown in Figure 11 below.



SA_SW3: Hemel Hempstead Road and Church End confluence, Redbourn Surface water flooding occurs frequently on Church End at the bottom of Redbourn. This is thought to be attributed to numerous defunct land drainage pipes which during high rainfall transport water downhill through North Common, along Hemel Hempstead Road towards Church End.

SA_SW6: Gaddesden Lane, Redbourn: Four cottages along Gaddesden Lane are repeatedly severely flooded from M1 runoff surcharging the balancing pond and flooding the road. This flooding may be reduced by the future M1 widening scheme.

SA_GW3: Gaddesden Lane, Church End: In Winter 2000/2001 properties in Hemel Hempstead Road flooded as Gaddesden Lane effectively became a river. This resulted in the road being closed for 6 months. This was caused by a combination of groundwater rising to the surface and land drainage from the fields north and south of Gaddesden Lane towards Church End.

Figure 11: St Albans District Council SFRA - Extract showing historical flooding

7 FLOOD MITIGATION AND RESILIENCE OPTIONS

7.1 INTRODUCTION

There is considerable scope to provide mitigation to reduce flooding. There is one surface water flood prevention measure already in existence which has scope to be improved. This section provides a brief overview of the various options available, they can be implemented individually or in combination. A description is provided of the relative merits and issues associated with each option. Budget cost estimates are provided for the construction of the options. Further detailed assessment will be required to establish accurate cost estimates if any is to be progressed further. A drawing of the proposed mitigation options is located in Appendix D.

7.2 MAINTENANCE ENHANCEMENTS

7.2.1 Locate, survey and clean highway drainage system

The existing highway drainage system could be very effective and offer considerable protection against flooding if existing gullies and pipework are kept clear of silt and other debris that restricts the removal of water from the road surface. The current arrangement of gullies is not, however, sufficient to prevent flooding because there are too few gullies. It is recommended that the entire system is cleaned using high pressure jetting and a CCTV survey conducted to establish any structural defects and restrictions that are inhibiting optimum hydraulic performance. The programme of routine inspection and reactive maintenance of gullies should be examined and where necessary more regular action taken. These actions should be implemented by Hertfordshire County Council Highways Department.

7.3 MITIGATION OPTIONS

The various mitigation options are summarised in the following Tables 8.1 to 8.5 on the following pages.

Ref:	Description
7.3.1	**Improvements to Highway Drainage – Surface Water Collection** There is scope to improve the collection of runoff from the east and west fields of Lybury Lane and install additional drainage measures in Ridgedown. We recommend cleaning all existing drainage related assets including gullies and all pipework to allow maximum flow capacity. There currently are two gullies positioned downstream of the three main field runoff points which frequently block with debris washed off the fields. We propose the installation of a full road width drainage channel, approx. 1m wide with adequate sized mesh (in similar fashion to a cattle-grid) and catch pit to capture debris and to collect all the surface water runoff off the road surface on Lybury Lane at the boundary between the houses and open fields. This will prevent surface water on the road being conveyed along Lybury Lane towards Rose Acre. Install a raise kerb to the eastern side of Lybury Lane between Rose Acre and Ridgedown to convey flows along the carriageway surface without spilling across the footpath and ionto the rear gardens of the properties in Rose Acre and Ridgedown. Raise the height of the road hump across the end of Rose Acre where it meets Lybrury Lane. Install additional road gullies and/or kerb drainage along Lybury Lane and at the low point in Ridgedown.
	Advantages: Improved collection and disposal of surface from Lybury Lane Ridgedown and reduced likelihood of blockage to gullies.
	Issues: Increased maintenance liability
	Budget Cost Estimate: £75,000

Table 8.1: Mitigation Option 7.3.1 - Improvements to Highway Drainage Surface Water Collection

Ref:	Description
7.3.2	**Reduce Field Runoff – Surface Water Collection** Look to minimise the amount of runoff from the east and west fields by installing an adequate size bund and containing water within the field. The bund will need to be installed on private land and may be subject to compensation claims due to loss of crops during a flooding event. The gradient of the field will determine the height of the bund required to contain the quantity of field runoff. At present the west field has a slight depression and raised bank which does prevent direct runoff on to the road, the flows convey through a cut out trench and spill into Lybury Lane. An option could be to formalise all known flood paths into a limiting discharge headwall and grille with a direct connection into the highway drain. This would rely on landownership agreement for installation and maintenance and will require a substantial catch pit to prevent blocking downstream pipework with debris. By providing a piped outfall and discharging directly into an open meshed grating as described in option 1.1 the access will be improved and maintenance liability reduced. This option is designed to capture flows more at source and limit the flow entering the downstream highway drainage system.
	Advantages: Capture all runoff from source and limit the amount of flow along Lybury Lane.
	Issues: Compensation claims, access to private property for maintenance.
	Budget Cost Estimate: £40,000

Table 8.2: Mitigation Option 7.3.2 – Reduce Field Runoff – Surface Water Collection

Ref:	Description
7.3.3	**Improvements to Highway - Modify Surface Profile and Kerb Details** A major factor in the cause of the flooding to Rose Acre was the conveyance of surface water along the carriageway of Lybury Lane and towards the properties at a low point in the road where kerb edgings are minimal. This option looks to increase the height of the kerbs at prone areas local to flooding properties. - The areas include the length of kerb edge in Rose Acre - The low point in Ridgedown from Snatchup to outside number 9 & 10 Ridgedown. - Install raised kerb between Rose Acre and Ridgedown as detailed in option 1.1. This is designed to contain flows in the carriageway and prevent overland flow into properties. Increase the road table at the entrance to Rose Acre to the highest possible level to prevent flows overtopping the speed table and encourage flows along Lybury Lane.
	Advantages: Provide protection measures against flows overtopping speed table and kerbs.
	Issues: This option will push more flow down Ridgedown and potentially cause greater flooding at this location if no other protection measures are implemented.
	Budget Cost Estimate: £50,000

Table 8.3: Mitigation Option 7.3.3 - Improvements to Highway, Modify Surface Profile and Kerb Details.

Ref:	Description
7.3.4	**Create Flood Storage Areas** Mitigation Options 1.1 & 1.3 will address the flooding issues experienced at Rose Acre but may consequently cause greater problems to properties in Ridgedown and Snatchup. Option 1.4 looks at the potential of creating an above ground flood storage area in the available permeable ground at the junction of Ridgedown and Lybury Lane. Proposals would require a raised speed table at the northern junction of Ridgedown and Lybury Lane with a dropped kerb on the southern side to encourage the overland flow path into the storage area. The Flood Storage Area could be designed by excavating on the west side and using the material to create a bund on the east side, this will maximise the storage capacity and if required a similar concept could be implemented on the east side of Lybury Lane although to a much greater cost due to the gradient of the land. Both Flood Storage Areas would need to be connected via an underground pipe with flows limited by a headwall before connecting back into the highway drain. Ground tests and further drainage investigations will need to be undertaken to determine the exact downstream pipe flow rate, the highway drainage capacity and the rate of permeable ground infiltration in the storage areas to ascertain whether the required storage volumes can be achieved. Calculations state a total runoff volume for a 1 in 1 year event = 4000m^3, 1 in 10 year = 7160m^3 and 1 in 100 year = 12000m^3. Detailed hydraulic analysis for the downstream highway drain will determine the maximum possible discharge rate and whether suitable storage can be accommodated within the allocated areas.
	Advantages: Preventative measure for all flooding in Rose Acre, Ridgedown and Snatchup. Although the most expensive, covers the highest level of flooding protection to the area.
	Issues: Further detailed hydraulic analysis required. The most expensive option and needs to be completed in line with option 7.3.1 to maximise protection.
	Budget Cost Estimate: £75,000 - £125,000

Table 8.4: Mitigation Option 7.3.4 – Create Flood Storage Area

Ref:	Description
7.3.5	**Flood Protection Measures to Individual Properties** Emergency protection measures are recommended to be fitted to each of the flood entry points at the properties that have been subject to flooding. Ideally these should be automated devices that are activated by the presence of approaching flood water, alternatively they can be fittings that require installation by the residents in advance of anticipated severe storm conditions. Grants are currently available from the local authority under certain conditions. The grant scheme is known as…. Local Government "Flooding Recovery: Repair and Renew Grant Scheme" Advice can be found at the following web site: *www.gov.uk/government/publications/flooding-recovery-households-and-businesses-applying-for-the-repair-and-renew-grant-scheme/flooding-recovery-households-and-businesses-applying-for-the-repair-and-renew-grant-scheme*
	Advantages: Protection to the inside of the properties
	Issues: Requires consent from the local landowners Dependence upon sufficient grant and/or top-up contribution from property owners Owner intervention required to install non-automatic flood barriers No protection to the gardens and driveways
	Budget Cost Estimate: £0 - £10,000

Table 8.5: Mitigation Option 7.3.5 - Flood Protection Measures to Individual Properties

7.4 BENEFIT:COST ASSESSMENT OF MITIGATION OPTIONS

The nature of the flood mechanism and disparity between the mitigation options in terms of the benefits they bring to different properties makes any direct correlation between the costs of mitigation and the value of benefits derived difficult. As an illustration of the mitigation measures that will achieve a significant, but not the maximum reduction in risk of flooding, comparisons of costs and benefits are presented below in Table 9. The second option combining of mitigation option 7.3.3 & 7.3.4 provides the greatest amount of protection against flooding for all properties.

The costs and benefits are approximate and accurate figures should be developed as part of detailed development of options.

Mitigation Option	Costs	Properties Benefitted	Benefit Value			
			1 in 10 yr	Benefit: Cost	1 in 100 yr	Benefit: Cost
7.3.1	£75,000	Rose Acre (8 No.)	£108,000	1.44	£119,000	1.59
7.3.3 & 7.3.4	£175,000	Rose Acre (8 No.), Ridgedown (5 No.), Snatchup (2 No.)	£315,500	1.80	£347,050	1.98

Table 9: Benefit : Cost Comparison for Selected Mitigation Measures

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

8.1.1 A total of 15 properties experienced internal flooding from surface water runoff during the storm event of 7 February 2014.

8.1.2 The flooding was the result of excessive surface water runoff from a combination of rural and residential urbanised catchment. The surface water runoff resulted from an intense rainfall event over a period of approximately 4.5 hours onto ground that was saturated from a period of prolonged rainfall over 4 weeks prior to the flood.

8.1.3 The natural topography of the catchment results in surface water runoff from an extensive and relatively steeply sloping rural catchment that is conveyed via Lybury Lane towards the properties in Rose Acre. Flood water also continued passed Rose Acre into an adjacent road and caused further flooding to properties in Ridgedown and Snatchup.

8.1.4 The properties in Rose Acre and Snatchup suffered severe flood damage and in some cases resulted in moving out into temporary accommodation, properties in Ridgedown suffered internal flooding in front and rear porch areas only.

8.1.5 There is only one existing drainage system present in the catchment:

- Highway drainage - responsibility of Hertfordshire County Council in its role as the Highway Authority

During the time of the survey the highway gullies looked reasonably clean and that regular maintenance is undertaken. Residents had photographic evidence that this is not always the case especially during the time of storm conditions when they can become rapidly blocked with debris washed off adjacent fields

8.1.6 Flooding is predicted to occur for storm events of a return period of 1 in 1 year and above. All properties suffer from the quantity of water flowing down Lybury Lane and ponding at two locations, in Lybury Lane adjacent to Rose Acre and in the 'Y' section of the road at the lower end of Ridgedown. At both locations the height of the existing kerbs are low and surface water runoff collects at this point and quickly builds up to a level above the kerbs with water flowing across the footpaths beside the road towards the properties in Snatchup that then are subjected to flooding.

8.1.7 There is scope for introduction of mitigation measures to improve the current drainage systems and to reduce the risk of flooding from surface water runoff.

8.2 RECOMMENDATIONS

8.2.1 Arrange for a programme of detailed investigation and cleaning of all of the existing drainage systems by the responsible Risk Management Authorities:

Highway Drainage: Hertfordshire County Council as the Highway Authority

8.2.2 Develop and implement a programme of planned inspection and maintenance for the existing drainage systems to ensure they operate at their optimum performance.

8.2.3 In addition to the investigation and maintenance measures stated above implement a series of mitigation measures to reduce the risk of flooding from surface water runoff for severe storm events and, at the same time, improve drainage arrangements for less severe rainfall conditions. The optimum combination of mitigation measures should include all of the following:

Option 7.3.1 Improvements to Highway Drainage – Surface Water Collection

Option 7.3.2 Reduce Field Runoff – Surface Water Collection

Option 7.3.3 Improvements to Highway - Modify Surface Profile and Kerb Details

Option 7.3.4 Create Flood Storage Areas

Option 7.3.5 Flood Protection Measures to Individual Properties

8.2.4 Of these options there are two that are recommend to be progressed in tandem as a priority. Option 7.3.1 and Option 7.3.3 will provide the most significant part of the potential benefit to the majority of affected properties. Protection measures to affected properties (Option 7.3.4) has the potential opportunity of grant from St

Albans District Council through the central government scheme and, if the flood barriers are installed, will avoid internal flooding until such time as other mitigation measures are implemented to reduce the overall risk of flooding.

8.2.5 Option 7.3.2 will reduce the flow and control the runoff from the fields in the upper part of the catchment. All works will require landowners consent and may have consequences of compensation claims but has added benefit controlling the water at source and limiting the flow towards the flooded properties.

APPENDIX A

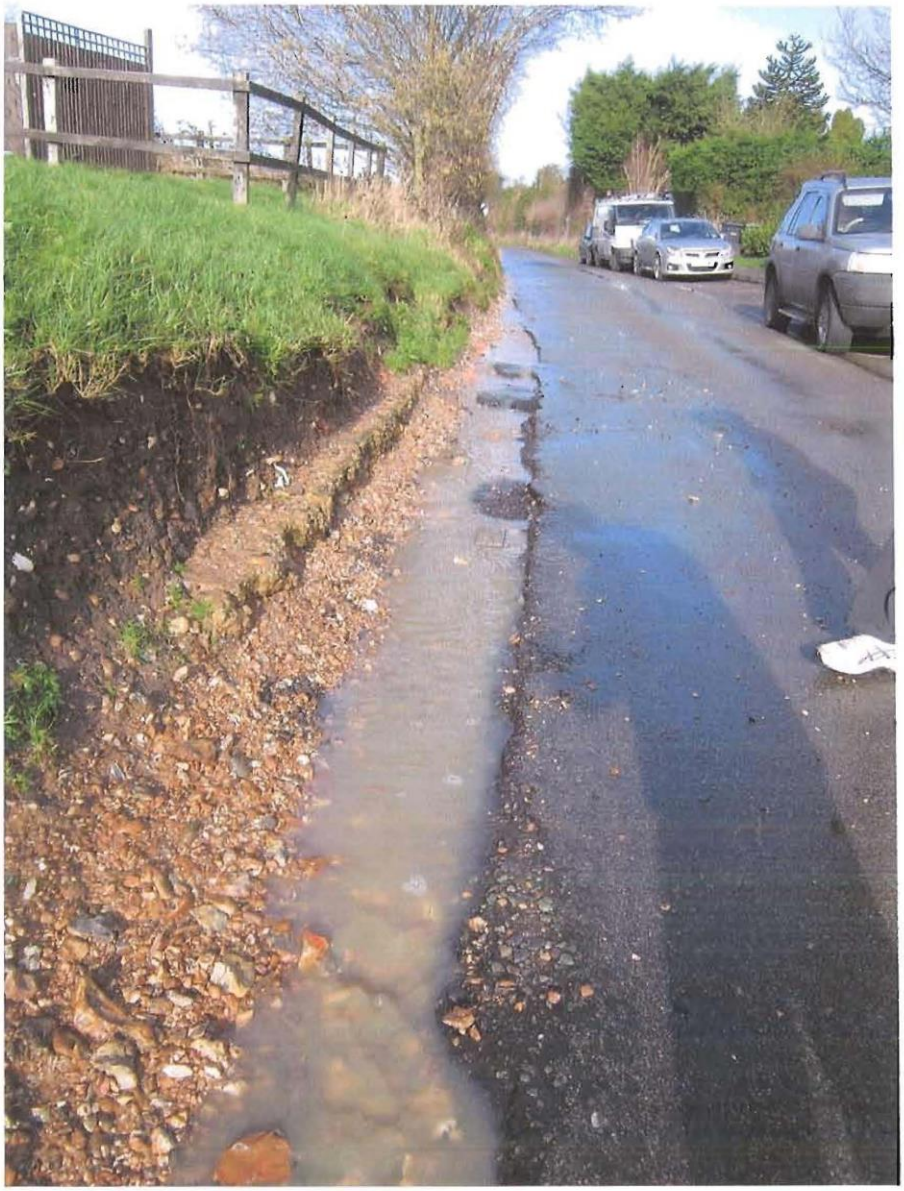
PHOTOGRAPHS OF FLOODING FROM THE EVENT OF 7 FEBRUARY 2014

Pictures taken 07/02/14 – Day of flooding

Top of Lybury lane – showing debris blocking drains.

Top of Lybury Lane – Debris blocking drains – Note the amount of debris on the grassed area that has already been hand cleared from the tops of the drains by local residents.

Midway down Lybury Lane – Debris swept by flood across whole road.



Top of Lybury Lane – Stream of water due to blocked drains further up the road. Note the erosion of the road. The drains have been blocked for several months which has caused this.

Top of Lybury Lane – Two blocked drains, completely full to the top with debris.

Top of Lybury Lane – Two blocked drains (photo taken 10/02/14).

APPENDIX B

Runoff Assessment of the storm of 7 February 2014

Saturated Catchment

NOTE: USE 1 IN 1 YEAR DESIGN STORM IN FLOOD2 (RAINFALL FIGURES CORRELATE CLOSELY TO A 1 IN 1 YEAR DESIGN STORM). STORM DURATION = 270 MINUTES

Catchment	Description	Area (ha)	Adjusted Area	Tc (mins)	Peak Discharge	Flow Channel		Depth of flow on Lybury Lane (m)	Total Volume of Runoff (m3)	In-catchment Storage (m3)	NET Volume of Runoff	Receptor For Runoff
					(assumes all contributory area is effectively impermeable due to saturation and runoff is equivalent to 5l/s/ha)			(using Manning formula)	(Ave rainfall intensity from a 1 in 1 year storm of 270 min duration. Input Tc = 54mins into FLOOD2. Ave i = 4.4mm/hr)			
			100% Perm @ 10% Imp for Flood 2									
1	Field (N)	20.4	2.04	45	102	Lybury Lane	W=4.4m, Gradient = 1 in 60		4039.2	274	4039.2	Roseacre / Ridgedown
					0.102			40mm				

http://www.calctool.org/CALC/eng/civil/manning

Slope of Ground	60	0.01666667	Channel Width	Flow Depth	CSA	Wetted Perimeter	Slope (3000mm over 84m = 1 in 30)	Q	
			4.4	0.04	0.176	4.48	0.016666667	0.105	m3/s
			4.4	0.05	0.22	4.5	0.016666667	0.15	m3/s
			4.4		0	4.4	0.016666667		m3/s
			4.4		0	4.4	0.016666667		m3/s
			4.4		0	4.4	0.016666667		m3/s
			4.4		0	4.4	0.016666667		m3/s

Manning coefficient for Redbourn Field Runoff = 0.025

APPENDIX C

Runoff Assessment of Design Storms

1 in 10 year Dry Catchment

NOTE: USE 1 IN 10 YEAR DESIGN STORM IN FLOOD2

Catchment	Description	Area (ha)	Adjusted Area 100% Perm @ 10% Imp for Flood 2	Tc (mins)	Peak Discharge (assumes rural contributory area is equivalent to 10% of total area as 100% impermeable)	Flow Channel		Depth of flow on Lybury Lane in front of Flooded Houses (using Manning formula)	Total Volume of Runoff (m3) (Ave rainfall intensity from a 1 in 10 year storm of 270 min duration. Input Tc = 54mins into FLOOD2. Ave i = 7.8mm/hr)	In-catchment Storage (m3)	NET Volume of Runoff	Receptor For Runoff
1	Field (N)	20.4	2.04	45	166	Lybury Lane	W=4.4m, Gradient = 1 in 60		7160.4	274	7160.4	Roseacre / Ridgedown
					0.166			52mm				

http://www.calctool.org/CALC/eng/civil/manning

Slope of Ground	60	0.01666667	Channel Width	Flow Depth	CSA	Wetted Perimeter	Slope (3000mm over 84m = 1 in 30)	Q	
			4.4	0.04	0.176	4.48	0.016666667	0.105	m3/s
			4.4	0.05	0.22	4.5	0.016666667	0.15	m3/s
			4.4	0.052	0.2288	4.504	0.016666667	0.16	m3/s
			4.4		0	4.4	0.016666667		m3/s
			4.4		0	4.4	0.016666667		m3/s
			4.4		0	4.4	0.016666667		m3/s

1 in 10 year Saturated Catchment

NOTE: USE 1 IN 10 YEAR DESIGN STORM IN FLOOD2

Catchment	Description	Area (ha)	Adjusted Area	Tc (mins)	Peak Discharge	Flow Channel		Depth of flow on Lybury Lane in front of Flooded Houses (m)	Total Volume of Runoff (m3)	In-catchment Storage (m3)	NET Volume of Runoff	Receptor For Runoff
					(assumes all contributory area is effectively impermeable due to saturation and runoff is equivalent to 9l/s/ha) 1 in 10 year runoff is approx 90% greater than a 1 in 1 year so 5l/s/ha is increased to 9l/s/ha)			(using Manning formula)	(Ave rainfall intensity from a 1 in 10 year storm of 270 min duration. Input Tc = 54mins into FLOOD2. Ave i = 7.8mm/hr)			
			100% Perm @ 10% Imp for Flood 2									
1	Field (N)	20.4	2.04	45	183.6	Lybury Lane	W=4.4m, Gradient = 1 in 60		7160.4	274	7160.4	Roseacre / Ridgedown
					0.1836			56mm				

http://www.calctool.org/CALC/eng/civil/manning

Slope of Ground		60	0.016667	Channel Width	Flow Depth	CSA	Wetted Perimeter	Slope (3000mm over 84m = 1 in 30)	Q	
				4.4	0.04	0.176	4.48	0.016666667	0.105	m3/s
				4.4	0.05	0.22	4.5	0.016666667	0.15	m3/s
				4.4	0.052	0.2288	4.504	0.016666667	0.16	m3/s
				4.4	0.056	0.2464	4.512	0.016666667	0.18	m3/s
				4.4		0		0.016666667		m3/s
				4.4		0		0.016666667		m3/s

1 in 100 year Dry Catchment

NOTE: USE 1 IN 100 YEAR DESIGN STORM IN FLOOD2

Catchment	Description	Area (ha)	Adjusted Area	Tc (mins)	Peak Discharge	Flow Channel		Depth of flow on Lybury Lane in front of Flooded Houses (m)	Total Volume of Runoff (m3)	In-catchment Storage (m3)	NET Volume of Runoff	Receptor For Runoff
					(assumes rural contributory area is equivalent to 10% of total area as 100% impermeable)			(using Manning formula)	(Ave rainfall intensity from a 1 in 10 year storm of 270 min duration. Input Tc = 54mins into FLOOD2. Ave i = 13.0mm/hr)			
			100% Perm @ 10% Imp for Flood 2									
1	Field (N)	20.4	2.04	45	279	Lybury Lane	W=4.4m, Gradient = 1 in 60		11934	274	11934	Roseacre / Ridgedown
					0.279			72mm				

http://www.calctool.org/CALC/eng/civil/manning

Slope of Ground	60	0.01666667	Channel Width	Flow Depth	CSA	Wetted Perimeter	Slope (3000mm over 84m = 1 in 30)	Q	
			4.4	0.04	0.176	4.48	0.016666667	0.105	m3/s
			4.4	0.05	0.22	4.5	0.016666667	0.15	m3/s
			4.4	0.052	0.2288	4.504	0.016666667	0.16	m3/s
			4.4	0.07	0.308	4.54	0.016666667	0.26	m3/s
			4.4	0.072	0.3168	4.544	0.016666667	0.28	m3/s

1 in 100 year Saturated Catchment

NOTE: USE 1 IN 100 YEAR DESIGN STORM IN FLOOD2

Catchment	Description	Area (ha)	Adjusted Area (assumes 40% imp +60% perm@100% imp equiv)	Tc (mins)	Peak Discharge (assumes all contributory area is effectively impermeable due to saturation and runoff is equivalent to 15.7l/s/ha) 1 in 10 year runoff is approx 317% greater than a 1 in 1 year so 5l/s/ha is increased to 15.7l/s/ha)	Flow Channel		Depth of flow on Lybury Lane in front of Flooded Houses (m) (using Manning's formula)	Total Volume of Runoff (m3) (Ave rainfall intensity from a 1 in 10 year storm of 270 min duration. Input Tc = 54mins into FLOOD2. Ave i = 13.0mm/hr)	In-catchment Storage (m3)	NET Volume of Runoff	Receptor For Runoff
1	Field (N)	20.4	7.548	35	320.28	Lybury Lane	W=4.4m, Gradient = 1 in 60		11934	274	11934	Roseacre / Ridgedown
					0.32028			78mm				

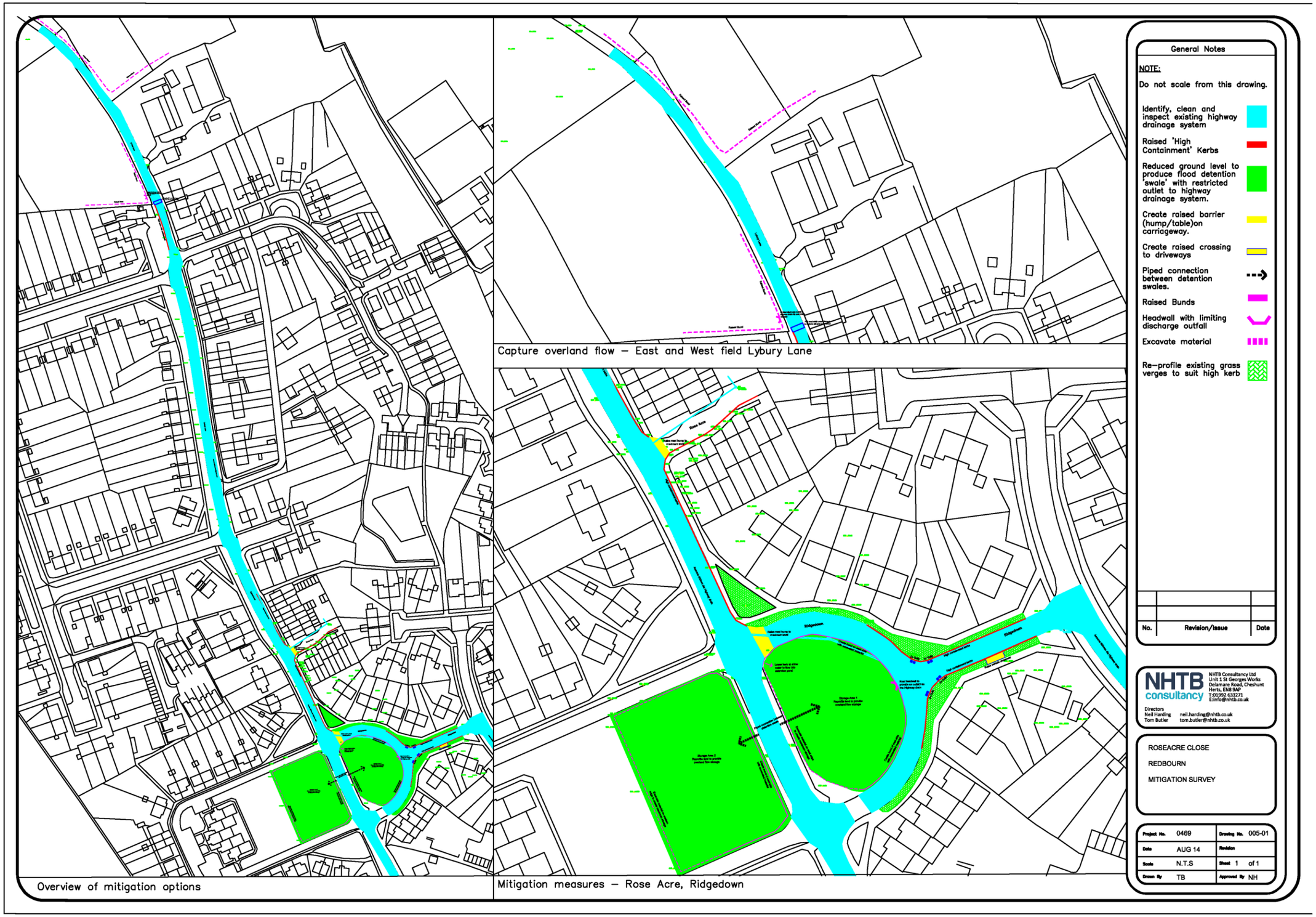
http://www.calctool.org/CALC/eng/civil/manning

Slope of Ground 60 0.01666667

Channel Width	Flow Depth	CSA	Wetted Perimeter	Slope (3000mm over 84m = 1 in 30)	Q	
4.4	0.04	0.176	4.48	0.016666667	0.105	m3/s
4.4	0.05	0.22	4.5	0.016666667	0.15	m3/s
4.4	0.052	0.2288	4.504	0.016666667	0.16	m3/s
4.4	0.07	0.308	4.54	0.016666667	0.26	m3/s
4.4	0.072	0.3168	4.544	0.016666667	0.28	m3/s
4.4	0.077	0.3388	4.554	0.016666667	0.31	m3/s
4.4	0.078	0.3432	4.556	0.016666667	0.32	m3/s

APPENDIX D

Proposed Mitigation Measures


Capture overland flow – East and West field Lybury Lane
Overview of mitigation options
Mitigation measures – Rose Acre, Ridgedown
General Notes
NOTE:
Do not scale from this drawing.
Identify, clean and inspect existing highway drainage system
Raised 'High Containment' Kerbs
Reduced ground level to produce flood detention 'swale' with restricted outlet to highway drainage system.
Create raised barrier (hump/table)on carriageway.
Create raised crossing to driveways
Piped connection between detention swales.
Raised Bunds
Headwall with limiting discharge outfall
Excavate material
Re-profile existing grass verges to suit high kerb
No.
Revision/Issue
Date
NHTB consultancy
NHTB Consultancy Ltd
Unit 1 St Georges Works
Delamare Road, Cheshunt
Herts, EN8 9AP
T:01992 633271
E:info@nhtb.co.uk
Directors
Neil Harding neil.harding@nhtb.co.uk
Tom Butler tom.butler@nhtb.co.uk
ROSEACRE CLOSE
REDBOURN
MITIGATION SURVEY
Project No. 0469
Drawing No. 005-01
Date AUG 14
Revision
Scale N.T.S
Sheet 1 of 1
Drawn By TB
Approved By NH