Hertfordshire County Council
Flood Investigation Report
Leyton Road, Harpenden
Hertfordshire

Leyton Road and Rothamsted Park in 2010
Aerial Photography © GeoPerspectives.co.uk

Hertfordshire

July 2016 Revision 4

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Rev	Date	Details	Author	Checked and Approved by
1	27/04/16	For internal FRM team consultation	Andy Hardstaff Flood Risk Management Team Leader HCC	John Rumble Head of Environmental Resource Planning HCC
2	19/05/16	Draft for issue to Risk Management Authorities following comments from FRM team	Andy Hardstaff Flood Risk Management Team Leader HCC	John Rumble Head of Environmental Resource Planning HCC
3	20/06/16	Draft for issue to resident and Risk Management Authorities following comments from RMAs	Andy Hardstaff Flood Risk Management Team Leader HCC	John Rumble Head of Environmental Resource Planning HCC
4	25/07/16	Final version for issue	Andy Hardstaff Flood Risk Management Team Leader HCC	John Rumble Head of Environmental Resource Planning HCC
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Explanation of Acronyms

Acronym / Term	Explanation
FWMA 2010	**Flood and Water Management Act 2010** – Legislation that was developed and enacted as a result of the review in to the serious flooding in 2.007. It brings new powers and duties to local authorities and other regulatory bodies.
HCC	**Hertfordshire County Council**
LDA 1991	**Land Drainage Act 1991** – Legislation that sets out a range of roles and responsibilities relating to flood risk management. It is also the legislation that gives powers to local authorities to manage flood risk and highlights the role of the landowner to manage watercourses on their land to maintain the flow of water.
LLFA	**Lead Local Flood Authority** – This is the role assigned to the unitary or county council for an area with a range of duties and powers to support the management of local flood risk.
RMAs	**Risk Management Authorities** – Bodies identified in the FWMA 2010 with roles and powers to manage flood risk. In Hertfordshire this includes the County Council, district councils, Highway Authority, the Environment Agency, the Bedfordshire and River Ivel Internal Drainage Board and water companies.
Adopted Highway	The term has been used in this report to include all highways maintainable at public expense. This includes historic highways as well as those formally adopted through section 38 of the Highways Act 1980 and preceding powers.
Antecedent	Antecedent moisture is a term that describes the relative wetness or dryness of a catchment, which changes continuously and can have a very significant effect on the flows during wet weather. Antecedent moisture conditions are high when there has been a lot of recent rainfall and the ground is moist. Antecedent moisture conditions are low when there has been little rainfall and the ground becomes dry.
Attenuation	The processes of water retention on site slowly being released to a surface water/combined drain or watercourse.
Bund	An embankment or causeway.
Mesoscale Convective System	A complex of thunderstorms that becomes organized on a scale larger than the individual thunderstorms but smaller than extratropical cyclones, and normally persists for several hours or more.
Storage	An area or structure where surface water flows are retained.
Swale	Broad, shallow and vegetated channels which are designed to store or transport excess runoff water and remove pollutants**.**

Executive Summary

On the evening of 15 July 2015 a high energy storm gave rise to an intense period of rainfall over Harpenden which led to excessive surface water runoff with 55mm of rain falling in just over two hours. Flooding occurred, starting late on 15 July and continuing into the early hours of 16 July 2015. A number of properties in the town were flooded internally including one in Leyton Road. This property had also flooded in February 2014.

Due to the severity of the flooding event and the fact that this was a repeat flooding incident for the property located in Leyton Road, Hertfordshire County Council (HCC) as Lead Local Flood Authority (LLFA) have investigated the flood incident under Section 19 of the Flood and Water Management Act (FWMA) 2010 and published this report. The aim of this report is to establish the causes of the flooding; identify the relevant Risk Management Authorities (RMAs), highlight their role and responsibilities and if appropriate confirm if those authorities intend to use their relevant powers to help manage the flood risk to Harpenden.

It has been concluded that the flooding on both occasions was as a result of excessive surface water runoff from a largely undeveloped catchment of agricultural land and extensive parkland; with an uncertain contribution from an area of housing and the adjacent sporting complex and car park.

In the February 2014 event rainfall over a number of days caused saturated ground conditions resulting in the permeable areas of the catchment effectively acting as impermeable surfaces, which led to high levels of run off.

In the July 2015 event the ground conditions are assumed to be dry and in this case the intensity of the rain was the critical factor.

There are good records of rainfall available from the agricultural research station at Rothamsted with a rain gauge within 750m of the investigation site. These records will help to understand the flooding mechanism in detail and inform any detailed modelling that may be required to fully understand the nature of the flood risk at this location.

The potential for any mitigation action to address the flood risk at this location is limited by the availability of resources to address the issue (due to the low standardised cost-benefit) and by the fact that the most effective works to address the flooding problem are likely to have to be located on land outside of the property owner’s and LLFA’s control.

1. Introduction

1.1 LLFA Investigation

Under Section 19 of the Flood and Water Management Act (FWMA) 2010 Hertfordshire County Council (HCC) as Lead Local Flood Authority (LLFA), on becoming aware of a flood in its area, must, to the extent that it considers it necessary or appropriate:

- investigate the incident;
- identify the Risk Management Authorities (RMAs) with relevant flood risk management functions;
- establish if the relevant RMAs have responded to the flood event or are proposing to respond;
- publish its findings; and
- inform the relevant RMAs of its findings.

As defined under Section 6, subsection 13 of the FWMA 2010, an RMA has certain powers to manage, regulate, assess and mitigate flood risk. We have identified the following RMAs as part of this Section 19 flood investigation for Leyton Road:

- HCC as LLFA
- City and District of St Albans as significant landowner
- HCC as landowner
- HCC as Highway Authority

At a public meeting following the storm event on 15/16 July HCC received a report that a residential property had suffered internal flooding in Leyton Road, Harpenden. In the course of discussion with the owner at the meeting it came to light that the property had also flooded in February 2014.

Due to the severity of the flooding, it was determined that this flood incident met the criteria in Policy 2 of HCC's Local Flood Risk Management Strategy[1], repeat flooding of a property within 10 years, and HCC subsequently started an investigation.

1.2 Site Location

Harpenden is located in the west of Hertfordshire, north of St Albans and south of Luton as shown below in Figure 1.1. The site where this investigation was carried out is located in the west of the town near the entrance to Rothamstead Park, see figure 1.2, with a contributing surface water catchment as shown in figure 1.3.

[1] http://www.hertsdirect.org/services/envplan/water/floods/floodrisk/lfrmsherts/

Figure 1.1 Harpenden, Hertfordshire – Location Map

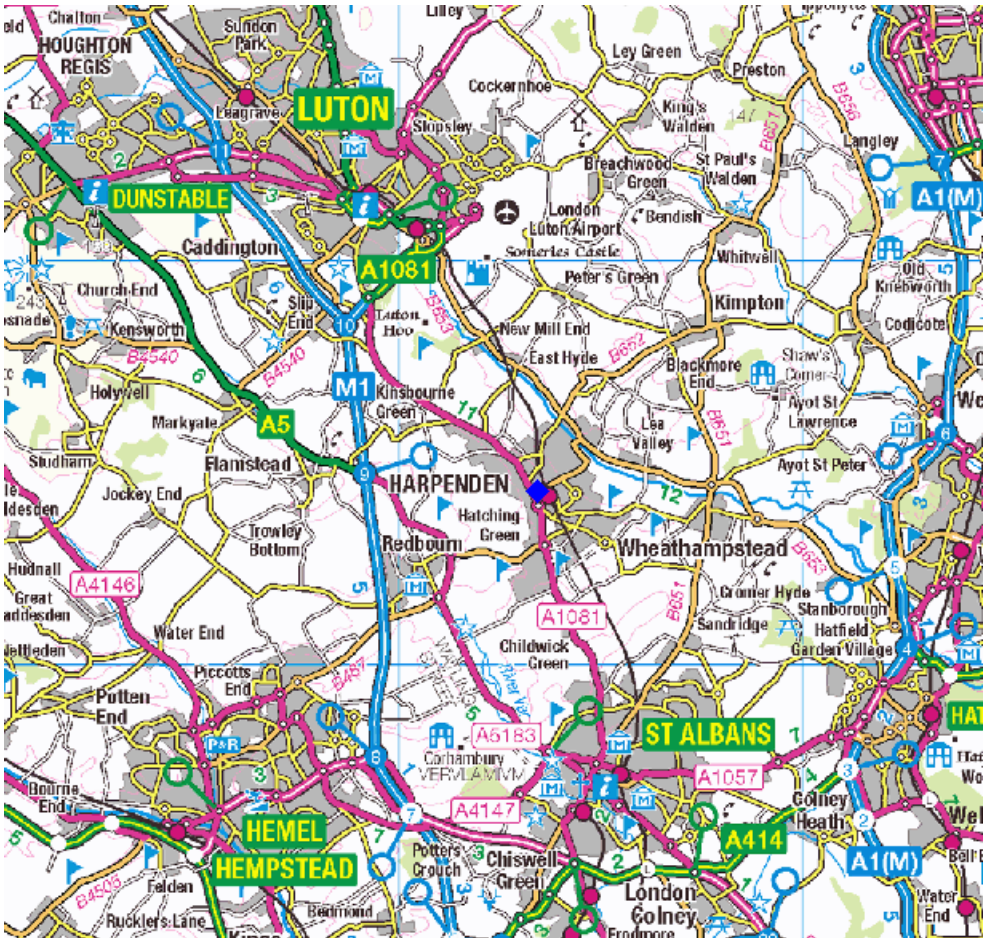


Figure 1.2 Area of investigation in Harpenden

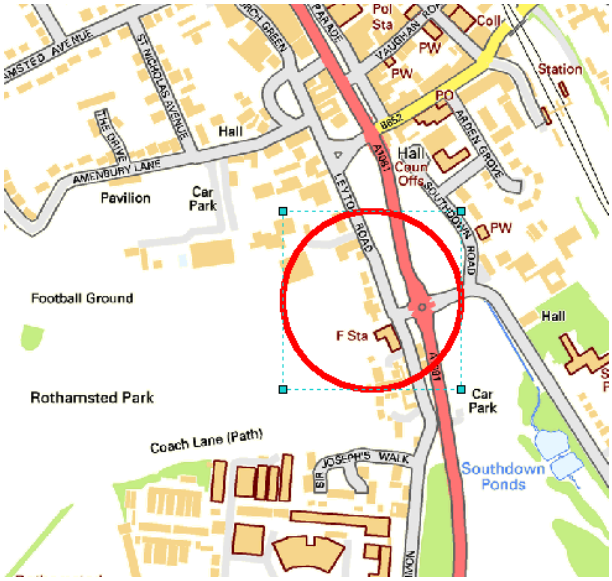
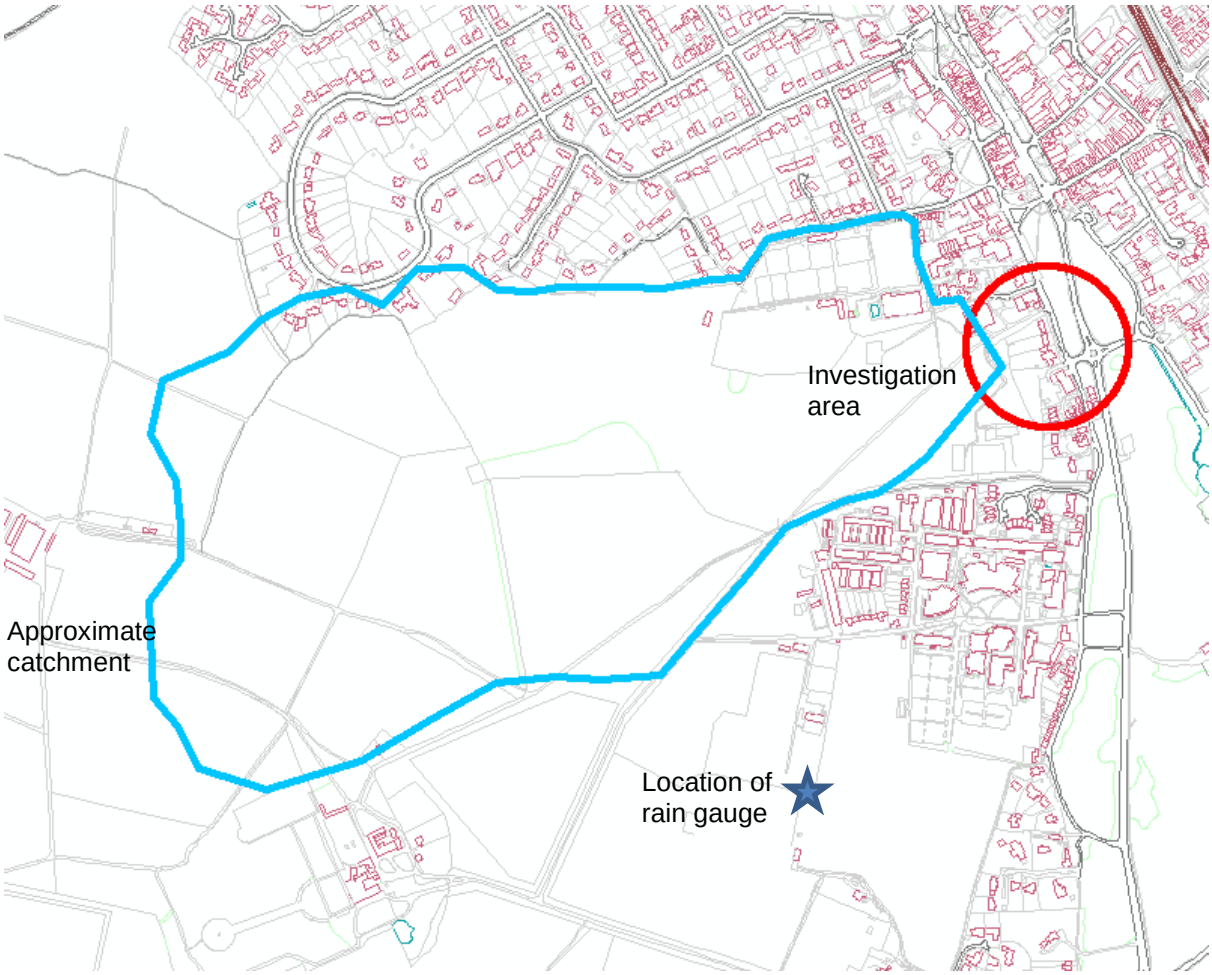


Figure 1.3 Catchment boundary



2. Background and History of flooding

2.1 Previous flood events

No flooding of this property has been reported other than the events of February 2014 and July 2015. There has been historical flooding reported more widely in Harpenden but the flood path affecting this property is separate from the main flow path through the town and differs in that a large proportion of the catchment is undeveloped and largely permeable (agricultural use and parkland) rather than a developed impermeable catchment (highways and buildings).

3. Assessment of the February 2014 and July 2015 flood events

3.1 Observations

During both the February 2014 and July 2015 flood events, water collected at a low point at the rear boundary of the property in Leyton Road and flowed through the rear garden entering the property through doorways which have thresholds lower than the surrounding area.

The flood water is thought to have two points of origin. What is assumed to be the greater proportion of the flow in the February 2014 event originates as natural surface water runoff in the Rothamstead Estate and Rothamstead Park area to the east, see figure 3.1 flow path B. There is also a second flow, which is believed to have had a much greater contributory effect in the July 2015 event, that starts from the south west corner of the sports complex and car park on Amenbury Lane adjacent to the swimming pool in the park, see figure 3.1 flow path A. There is a third flood path along Leyton Road (fig 3.1 flow path C) which causes flooding in Leyton Road but does not contribute to flooding of the property.

Flood flows have been observed running along the line of the pathway which runs from the car park past the sports centre and into Rothamstead Park, see figure 3.2.

Figure 3.1 Indicative overland flow paths

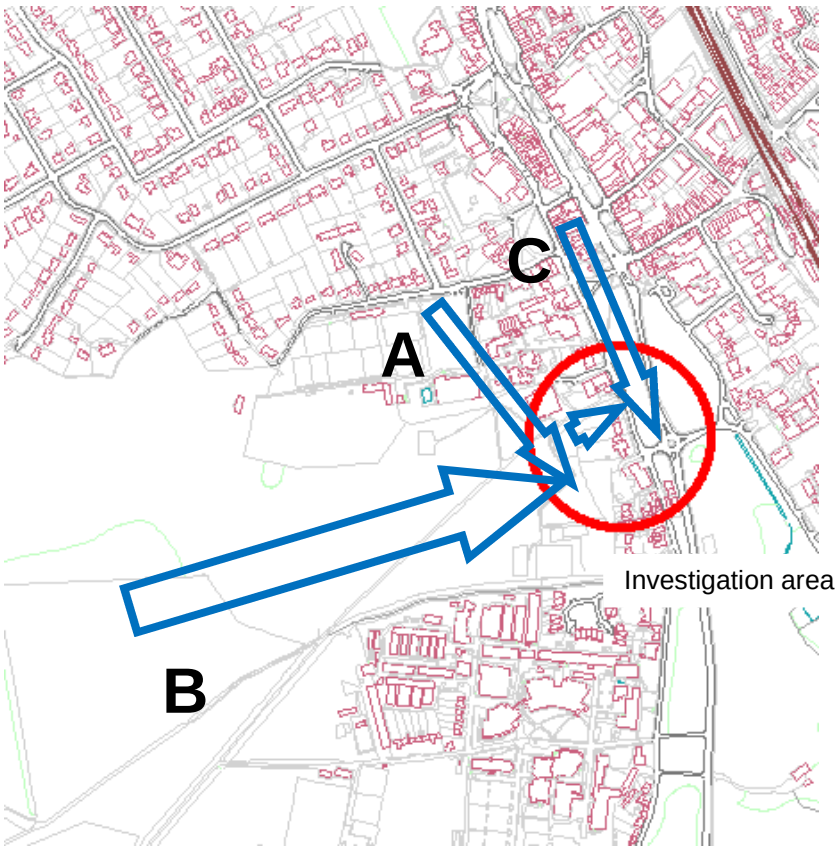
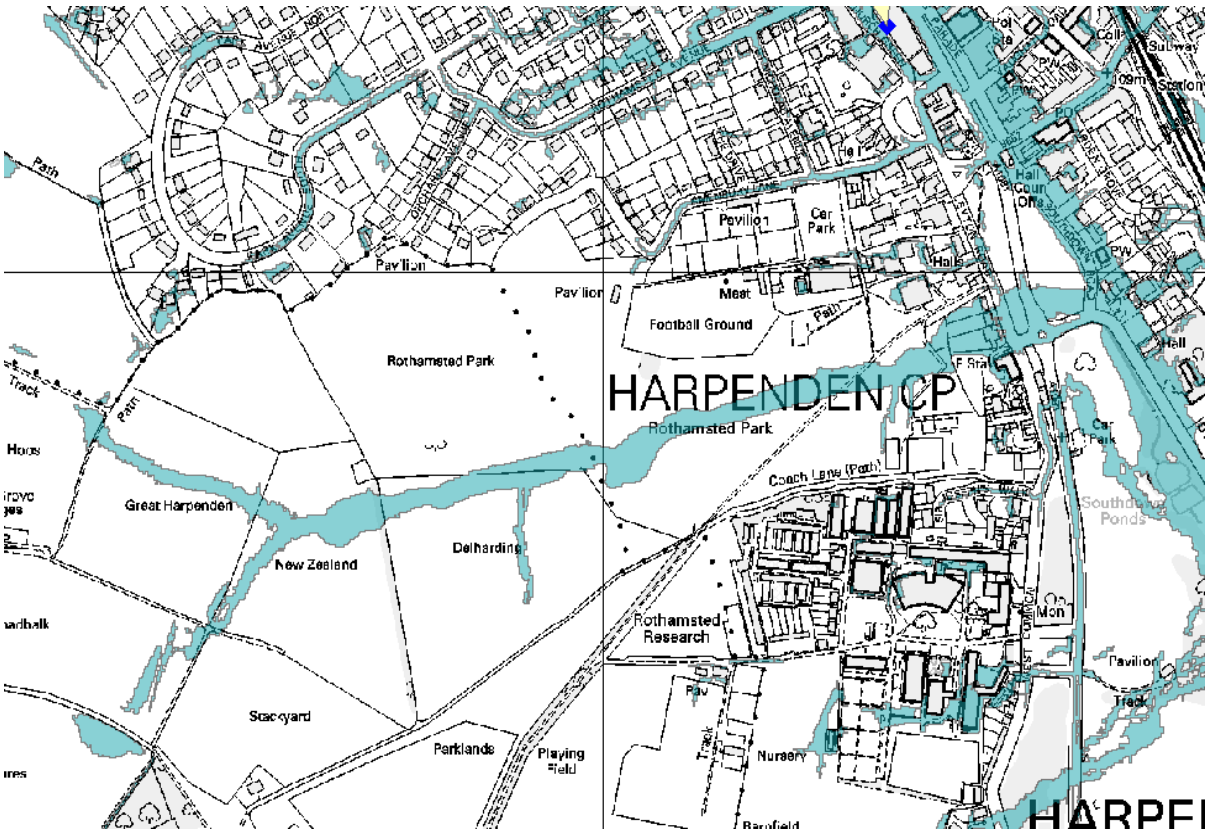


Figure 3.2 Modelled overland flow paths



Extract from national Updated Flood Map for Surface Water showing 0.1% probability flood extent. Environment Agency © Crown copyright and database rights 2016 Ordnance Survey 10.0019606

3.2 Rainfall and antecedent conditions

Extracts of hourly rainfall data together with mean volumetric soil moisture (%v/v) for the periods 24/01/2014 to 15/02/2014 and 14/07/2015 to 17/07/2015 have been kindly provided from the Environmental Change Network (ECN) automatic weather station at Rothamsted Research and are set out at Appendix 1. The geology of the catchment will vary but the soil moisture figure can be used as a proxy to indicate the degree of soil saturation in the catchment.

The notable points are for the:

- February 2014 flooding, the storms around the 7 and 14 February were heavy but not exceptional. (7 February 20.1mm in 3 – 4 hours, 14 February 12.2 mm in 15 – 16 hours).
- Whole of the period 24/01/2014 to 15/02/2014 (including the date ranges omitted from the appendix for clarity) the mean volumetric water content of the soil was around the point of saturation with the figures varying by a few tenths of a percentage point.
- July 2015 flooding 57.1mm of rain fell in 3 – 4 hours which is exceptional.

Figure 3.3 Flood flow path through Amenbury Lane car park

Figure 3.4 Flood flow along path from Amenbury Lane car park

3.3 Ground conditions

The flooding events were recorded following a period of saturated ground conditions in February 2014 and following a period of assumed dry ground conditions in July 2015. The catchment is estimated to be 85% permeable (due to the agricultural land and playing fields) and 15% impermeable from the remaining urban area which contributes to the runoff through Amenbury Lane car park. When saturated, however, the whole catchment would effectively be impermeable and therefore representative of a 100% urbanised catchment.

3.4 Sources of flooding

It is assumed that the flooding was due to surface water, largely surface runoff with some contributory flows from the urbanised area which may include surcharge from drains.

3.4.1 Surface water runoff (pluvial)

The approximate catchment is illustrated in figure 1.3. It has an area in the region of 60,000m^2 and an average gradient of 1:40 falling from a height of 130m in the west of the catchment to 105m in the east over a distance of approximately 1 km.

The catchment is made up of about 50% agricultural land, 40% grass parkland and 10% paved areas, buildings and sports pitches. The catchment drains naturally on the surface and through infiltration; there is nothing on record or visible on the ground to suggest the presence of a significant surface water drainage system.

The surface drift geology is classified as clay with flints and although it is regionally derived data it is indicative that the catchment will not likely to freely infiltrate beyond the surface layers which are cultivated or are permanent grassland. The majority of the catchment will drain naturally. Rain falling on the surface will infiltrate to a greater or lesser extent and then flow towards the east either on or just below the surface. There will be some losses due to deep infiltration or evaporation dependant on the prevailing conditions.

3.5 Surface Water and Sewerage (Thames Water Utilities Limited)

There is no known surface water or foul sewers which are thought to contribute to the flood runoff from the catchment. The only mapped public surface water sewer in the vicinity is 225mm in diameter and runs down the lower section of Amenbury Lane starting from the end of Hay Lane. There may be more public sewers connecting to this, not yet surveyed but that would have been transferred from private ownership to Thames Water following the regulations[2] which came into force on 1 July 2011. The majority of properties in the area are thought to drain to soakaways.

[2] The Water Industry (Schemes for Adoption of Private Sewers 2011

There are public sewers running along Leyton Road which may contribute to flooding in the road at the front of the property. A 225mm foul sewer runs along the length with a branch running eastwards under Bull Road from the vicinity of the fire station to join with a 525mm sewer in Southdown Road.

The 600mm surface water sewer runs south along Leyton Road to a point just outside of Park Hall it then runs south eastwards across the common with a slight dogleg to discharge in the watercourse which links to the ponds adjacent to Southdown Road.

3.6 Possible causes of flooding

The flood waters affecting Leyton Road resulted from large volumes of surface runoff generated due to exceptional rainfall and antecedent conditions. The likely flow paths are shown on the cover illustration which show predicted flooding from rainfall modelling for an event with a 1% annual probability and at figure 3.1which shows flows which have been observed. The differences in predicted and observed flow routes will stem from the resolution of the modelling which may not always pick up the subtle features and drainage networks which influence surface water flow paths.

The storm which led to the flooding in February 2014 was not extreme in itself but the context in which it fell was exceptional. The winter of 2013/14 was one of the wettest on record and the weeks leading up to the 7 and 14 February were characterised by heavy storms crossing the Atlantic at approximately four day intervals. This led to the ground becoming saturated. Any engineered drainage systems would have been running at capacity with little opportunity to drain down in order to recover space to provide storage for rain water. Soakaways are likely to have been at capacity and therefore ineffective during this period with a result that the majority of rain failing on the developed or undeveloped area of the catchment will have contributed to the surface water flooding.

The storm which led to the flooding in July 2015 was extreme; with an annual probability of occurring in the region of 0.7% or alternatively expressed as a return period of 1 in 150 years. Over 2 inches of rain (55mm) fell in approximately two hours due to warm moist air meeting an area of colder air lying across the south east corner of the UK. This lead to the formation of a line of violent storms known as a Mesoscale Convective System; which tracked slowly north-eastwards along a line from the Isle of Wight to Cambridge and beyond, in the evening and early hours of 15 and 16 July 2015. The intensity of rainfall would have meant that only a limited proportion of the rain falling would have chance to infiltrate with the majority running over the surface and with any local drainage linked to soakaways being overwhelmed.

In both of these flood events the potential for runoff generation is increased due to the gradient of the slope in the parkland (see figure A2).

The contribution made to the flooding by the runoff from the Amenbury Lane car park is uncertain. A surface water flood has been observed and a video is available. The fall of the car park will cause water to flow across the surface towards the south east corner where there are two drainage grids which are understood to feed a soakaway.

There is also an overflow set into the kerb by the grids which suggest an ongoing problem with drainage due to capacity issues with the soakaways see fig 3.3. This picture was taken on 4 May 2016.

There is some flooding at the front of the investigation property as a result of flow running down Leyton Road which may be surcharge from the surface water and a proportion of the flows through Rothamsted Park which follow the line of the drive and pass through the main entrance onto Leyton Road.

4. Responsible authorities and landowners

HCC as the LLFA has investigated the flooding at Leyton Road, Harpenden to establish the relevant RMAs that have Flood Risk Management Functions in accordance with the FWMA 2010. Those RMAs and their relevant powers and functions are set out below.

4.1 Hertfordshire County Council as Lead Local Flood Authority

HCC as the LLFA for Hertfordshire has fulfilled its responsibility to carry out a Flood Investigation under Section 19 of the FWMA 2010, to;

1. Identify the relevant RMAs and;
2. Establish if those authorities intend to utilise their own powers and to what extent. The actions that the relevant RMAs have agreed to take are set out in Section 6.

In order to achieve the responsibilities under Section 19, HCC as LLFA must first establish the cause and impacts of the flooding and then, where possible, identify actions to reduce flood risk.

HCC as the LLFA for Hertfordshire has powers to carry out flood risk management works for flooding from surface runoff and ground water in accordance with the Local Flood Risk Management Strategy for Hertfordshire.

4.2 The City and District of St Albans as Local Planning Authority

The City and District of St Albans are the local planning authority for the Harpenden area and their role is to determine planning applications for new development, approve and assess any impacts from all sources of flooding and any associated proposed drainage.

4.3 The City and District of St Albans as landowner

The City and District of St Albans own and manage Rothamstead Park, Amenbury Lane car park, the swimming pool adjacent sports pitches and the sports centre.

4.4 Hertfordshire County Council as Highways Authority

HCC are the responsible authority to maintain and manage adopted highways including associated drainage infrastructure such as gullies, drainage pipes, and soakaways etc. which have been provided for the sole purpose of draining the public highway.

Leyton Road is adopted highway and is impacted by the flooding, Amenbury Lane and Hay Lane are also adopted highways.

HCC as the Highways Authority have powers to manage water falling on an adopted road under the Highways Act 1980, however where this water originates from third party land and not from runoff from the highway these powers are limited.

HCC as the highway authority is required, as far as is reasonably practicable, to keep highways open and usable by the public.

In extreme flood events the majority of excess surface water will eventually flow onto the highway as roads act as manmade conduits for such water

In such extreme conditions allowing water to flood the public highway may help to avoid or reduce flooding to property, and generally any flood water will eventually flow onto the public highway from the flooded properties anyway.

Where flooding on a highway is caused by another person (e.g. an adjoining landowner), the Highway Authority can take action against the person responsible.

Such a situation may be tolerated if this only occurs in extreme rainfall events and not every time it rains and properties would otherwise flood internally.

However if flooding starts to happen frequently or has a detrimental effect on the highway or property in the future, the situation will be reviewed and evaluated with appropriate action then being taken.

4.5 Hertfordshire County Council as landowner

The county council owns land adjacent to Leyton Road in the vicinity of the Fire Station.

4.6 Other landowners in the catchment

The upper part of the catchment is in the estate of Rothamstead Research. The common is owned and managed by Harpenden Town Council.

5. Conclusions, potential mitigation options and recommendations

5.1 Conclusions

The flooding was the result of excessive surface water runoff. The county council as Lead Local Flood Authority is the relevant risk management authority with the discretionary powers to manage flood risk due to surface runoff. The county council does not have any enforcement powers relevant to this situation.

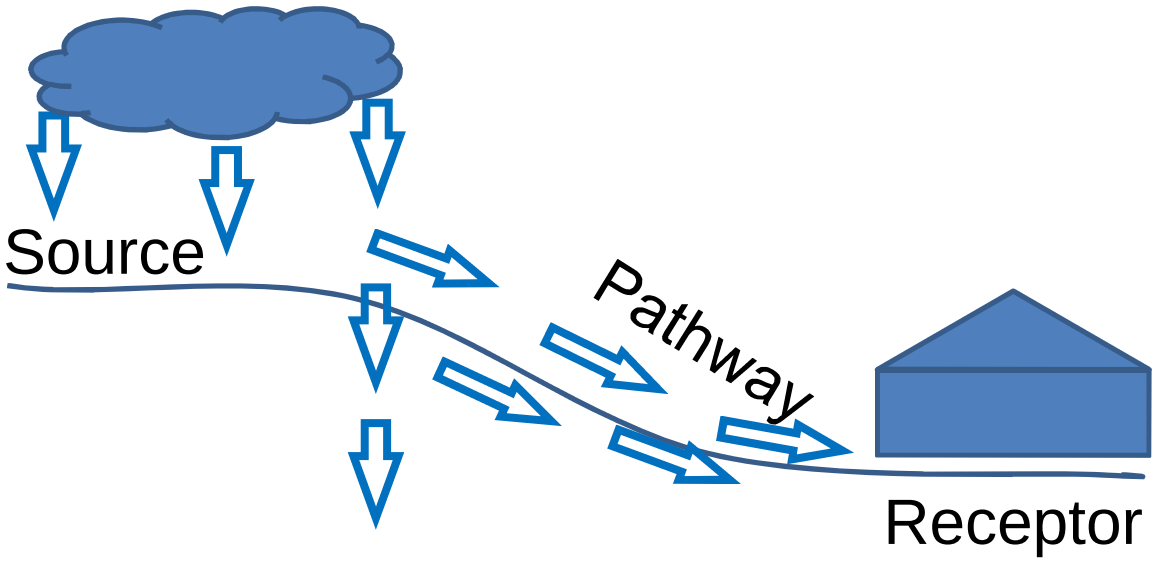
There are unlikely to be any significant contributions available from national sources or from the LLFA. Management of flood risk is legally required to be proportionate and risk based and in this case only a single property was affected by two extreme weather events which by unfortunate coincidence occurred in an 18 month period.

It is acknowledged that flooding is hugely disruptive to people's lives and has the potential to have a devastating impact. However the government guidelines for the valuation of impacts and scheme costing are based on standard property costs and do not take account of individual circumstance.

5.2 Potential mitigation options

It is useful to use Source, Pathway, Receptor concept to categorise the potential options for managing the flood risk, see figure 5.1.

Figure 5.1 Source pathway receptor concept of flooding



What is thought to be the major source in this case is runoff from agricultural land and an area of grassy parkland. There is an unknown contribution from the Amenbury Lane car park.

Along the flood pathway through the park there may be potential to intercept the flow

and direct it to areas where flows can be attenuated and stored temporarily, however drain down to free up the storage would be necessary.

There are constraints to diverting the flood pathway. The likely result is putting more floodwater more quickly onto Leyton Road which would be of concern to the county council in its role as the Highway Authority.

There is a limited opportunity to increase the resilience of the receptor (the property in Leyton Road) as it is a listed building and sections of it are below the surrounding ground level which means there will be a relatively greater depth of flood water above threshold level.

For all these options an assessment of the potential volumes of flood flows needs to be understood for a baseline scenario and how this would change for each of the options below so that the most effective approach(es) can be assessed.

It may be possible to link management of flood risk to schemes with other benefits such as landscaping and amenity projects in the park. HCC as Highway Authority and the Fire and Rescue Service might consider supporting schemes that would improve the flood resilience of the highway and the fire station.

Options and issues are set out below. The numbering of the options links them to any corresponding issues.

5.2.1 Management of surface water flows through the parkland catchment

Potential options:

1. Adjust land management practice to increase infiltration and natural attenuation of surface flows. This could include the planting of hedge lines and creation of ditches.

2. Create areas of attenuation along and adjacent to the flood flow path for example taking advantage of the natural hollows.

3. Create swales to temporarily store and direct water away from the affected properties

Advantages:

This would tackle flood flows close to source and potentially disperse the attenuation and aid the draining of flood flows over a large area. Maintenance requirements would largely be as at present apart from any engineered structures to drain down and the periodic maintenance of any planting. There is also the potential for environmental enhancement and benefit.

Issues:

1. There are long term and experimental cultivation regimes at Rothamstead Research which might be disrupted by changes in land management

practices. Some changes would have to be adopted as part of any ongoing cultivation practice.

2. The drain down requirements for any attenuation areas would have to be engineered. These areas would remain wetter for a greater proportion of the year than is currently the case and would impact on general access.

3. There may be restrictions to access and any change in flood risk would need to be understood if the water is directed along the line of the main drive onto Leyton Road. This would work best where gradient is flattest.

Additionally:

4. All these proposals would require the agreement and participation of the relevant landowners. Sources of funding uncertain.

5. Any works related to larger features may require planning permission.

Budget cost estimate: £20,000 to £30,000 plus ongoing maintenance.

Include in Recommendations? Yes (with further investigation needed first).

5.2.2 Management of surface water flows through the car park

Potential options:

1. Intercept flows across the car park and direct away from the current flow path.

2. Intercept flows across the car park and reduce the volume of flows by directing water to rain garden plantings.

3. Raise the downstream boundary of the car park to allow flood flows to be stored in the car park.

4. Create areas of underground storage.

5. Permeable paving of the car park in combination with shallow underground storage.

Advantages:

This would manage the contribution to flood flows close to source and disperse them over a larger area. Potential pollutants would be retained in the car parking area.

Issues:

1. The only alternative route would be onto the public highway via Amenbury Lane which is likely to increase flood risk elsewhere.

2. This could potentially reduce the number of car parking spaces and the

impact is uncertain as reduction of flood flows has not yet calculated.

3. May temporarily reduce the number of car parking spaces. May need to exclude cars from the area permanently to prevent incidents during flooding. Drain down of the water may be problematic, would need to control infiltration of pollutants.

4. Would need to close areas of the car park during construction. Likely to be expensive to install and have a limited design life. Size required still needs to be calculated.

5. Would need to close areas of the car park during construction. Drain down of the water may be problematic, would need to control any potential for the infiltration of pollutants

Additionally:

6. Runoff from the sporting complex may be entering the car park, this would need to be verified along with the potential volume of runoff from the car park.

7. Resurfacing of the car park solely to manage flood risk would not satisfy the cost benefit appraisal required for flood risk management schemes.

Budget cost estimate: £150,000 to £250,000.

Include in Recommendations? Yes with qualification. Any contribution from the car park to the flood flows is uncertain. If the car park is reconfigured or resurfaced in the future it would present an opportunity for the cost effective incorporation of techniques to manage surface water flow.

5.2.3 Management of surface water flows past properties onto Leyton Road

Potential option:

1. Use swales or a combination of swales and bunds to capture flood flows and direct them around the properties onto Leyton Road and the two areas of common beyond (see figures 5.1 and 5.2).

Advantages:

Keeps water away from the property(ies) and would reduce flood risk from both flood pathways.

Issues:

1. Getting flows across Leyton Road. The area needed for storage on the areas of common is not known. Drain down of attenuation storage areas would have to be engineered. These areas would remain wetter for a greater proportion of the year than is currently the case and would impact on general access. Potential for flooding the main road A1081 would need to be

investigated. Highway authority could take action to prevent intentional flooding of the Highway. Town Council and potentially Secretary of State for the Environment would have to consent to works on the common. The roots of the trees will limit the scope for excavation.

There is a line of kerb inlet drainage on the corner of Leyton Road opposite the Fire Station (see fig 5.1 point A) which has been installed since June 2011. At the time of writing this report the onward connection from this area has not been established but is likely to be to a connection to the surface water sewer or high capacity soakaway.

There are also two inlets on this area of common adjacent to the A1081 the function of which has not been established at the time of writing. It needs to be investigated if they provide an onward connection to drain this area towards Southdown Ponds.

Budget cost estimate: £15,000 – £25,000.

Include in Recommendations? Yes (with further investigation needed first).

Figure 5.1 Leyton Road and A1081 looking north

Figure 5.2 Leyton Road and A1081 looking south

5.2.4 Measures to prevent flooding to rear of property

Potential options:

1. The property owner(s) could create a barrier on the curtilage of their property(ies).

2. A barrier could be built as above together with an area of storage in the park.

Advantages:

Could be a compact scheme under property owners' control. Barrier and storage would reduce flood risk from both flood pathways.

Issues:

1. Water likely to be displaced into adjacent properties and potential for increased flood risk to main road.

2. The volume needed for storage in the park is not known. Drain down of attenuation storage areas would have to be engineered. The area would remain wetter for a greater proportion of the year than is currently the case and would impact on general access.

Additionally:

3. Any proposals in the park would require participation of the relevant landowners.

4. Larger features may require planning permission.

Budget cost estimate: £5,000 - £50,000.

Include in Recommendations? Yes (with further investigation needed first).

5.2.5 Measures at property level

Potential options:

1. The property owners could install property level protection sealing doors, airbricks and other entry points into the building.

2. An automated barrier system at a distance from the house would potentially be an option.

Advantages:

Totally within the control of the property owner (although would be subject to listed building consent).

Issues:

1. The listing and construction of the building severely limits the options for property level protection. Conventional cam locking doors with seals would be inappropriate. Also as sections of the building are below the immediate ground level barrier methods would have to be supplemented with a pumping strategy to clear water from the exterior of the building within a reasonable period of time as it is of unconventional construction and would be difficult to waterproof.

2. An automated barrier system would have some of the additional issues as listed under 5.2.4 that water is likely to be displaced into adjacent properties and there is subsequent potential for an increase in flood risk to the main road. It would also require periodic testing and maintenance. It may also require listed building consent at it would have an impact on the main building's context and setting.

Budget cost estimate: £20,000 to £145,000.

Include in Recommendations? No.

5.3 Recommendations

The following are the recommendations of the county council, in its capacity as LLFA and follow from the main findings from the Section 19 flood investigation carried out into the flood event in Leyton Road in February 2014 and July 2015.

No.	Recommendations	Comments	RMAs and other parties to be involved
1.	See 5.2.1 above The feasibility of changes in land management practices is investigated.	This would be to investigate the potential for changes to the management of the agricultural land and park. Any planned landscaping improvements may present an opportunity for such work to be carried out at reasonable cost with minimal impact.	• City and District of St Albans, other landowners
2.	See 5.2.2 above That cost effective measures to modify flows in the car park are investigated.	It would be preferable for the flows from the car park to be managed close to the source, but there is the option of intercepting flows further down the flow path in the park. Any future plans to resurface or remodel the car park should consider options to manage surface water flows so flood risk benefits could be gained for proportionately less cost..	• City and District of St Albans
3	See 5.2.3 above Investigate the feasibility of swales and associated structures to capture and direct flood flows.	It would be preferable to manage water on the surface as this would reduce cost of construction and increase the visibility of required maintenance. However there would be issues to be overcome in getting the water across Leyton Road and potentially the A1081.	• City and District of St Albans, Harpenden Town Council, HCC as Highway Authority
4.	See 5.2.4 above The feasibility of a barrier at the curtilage of the property is investigated.	This requires further analysis of the impact of diverted flows on neighbouring properties and the highway.	• City and District of St Albans and HCC as land owners, HCC as Highway Authority, neighbouring properties.

6. Next Steps and Actions

6.1 Lead Local Flood Authority

The following are agreed actions to be undertaken by HCC in its capacity as LLFA;

1. To distribute final copies of the report to all relevant Risk Management Authorities and other appropriate parties.

2. LLFA to investigate with SADC the potential to carry out landscaping changes in Rothamsted Park and to explore with other landowners the potential for changes in land management to slow water flows.

3. LLFA to investigate with SADC the potential to create swales in the lower area of Rothamsted Park especially to manage the flows from Amenbury Lane car park.

4. LLFA to confirm with HCC as Highway Authority the extent of any drainage in the common adjacent to Leyton Road and the nature of any linked storage or onward connections.

7. Disclaimer

This report has been prepared as part of Hertfordshire County Council's responsibilities under the Flood and Water Management Act 2010. It is intended to provide context and information to support the delivery of the local flood risk management strategy and should not be used for any other purpose.

The findings of the report are based on a subjective assessment of the information available by those undertaking the investigation and therefore may not include all relevant information. As such it should not be considered as a definitive assessment of all factors that may have triggered or contributed to the flood event. Hertfordshire County Council expressly disclaims responsibility for any error in, or omission from, this report arising from or in connection with any of the assumptions being incorrect.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the time of preparation and Hertfordshire County Council expressly disclaim responsibility for any error in, or omission from, this report arising from or in connection with those opinions, conclusions and any recommendations.

Hertfordshire County Council does not accept any liability for the use of this report or its contents by any third party.

Appendix 1

Rainfall data provided by the Environmental Change Network (ECN) automatic weather station at Rothamsted Research.

Extracts of hourly rainfall together with mean volumetric soil moisture (%v/v) for the periods 24/01/2014 to 15/02/2014 and 14/07/2015 to 17/07/2015.

Date	Time (24hrs)	Rainfall (mm)	soil moisture (%v/v)
24/01/2014	18.00	0	50.7
24/01/2014	19.00	0.2	50.7
24/01/2014	20.00	0.8	50.7
24/01/2014	21.00	1.7	50.7
24/01/2014	22.00	1.4	50.8
24/01/2014	23.00	0.8	50.8
24/01/2014	24.00	0.8	50.8
25/01/2014	01.00	0.4	50.8
25/01/2014	02.00	0	50.8
25/01/2014	03.00	0.2	50.8
25/01/2014	04.00	0	50.8
26/01/2014	09.00	0	50.7
26/01/2014	10.00	0.6	50.7
26/01/2014	11.00	3.1	50.7
26/01/2014	12.00	2.1	50.7
26/01/2014	13.00	1.7	50.7
26/01/2014	14.00	1.7	50.6
26/01/2014	15.00	1	50.6
26/01/2014	16.00	0	50.6
29/01/2014	08.00	0	50.5
29/01/2014	09.00	0.4	50.5
29/01/2014	10.00	1.9	50.6
29/01/2014	11.00	1.4	50.6
29/01/2014	12.00	1.2	50.6
29/01/2014	13.00	0.8	50.6
29/01/2014	14.00	1	50.6
29/01/2014	15.00	0.8	50.6
29/01/2014	16.00	0.6	50.6
29/01/2014	17.00	0.8	50.6
29/01/2014	18.00	0.8	50.6
29/01/2014	19.00	0	50.6
29/01/2014	20.00	0.4	50.6

Date	Time (24hrs)	Rainfall (mm)	soil moisture (%v/v)
29/01/2014	21.00	0.4	50.6
29/01/2014	22.00	0.8	50.6
29/01/2014	23.00	0.4	50.6
29/01/2014	24.00	0.4	50.6
30/01/2014	01.00	0.2	50.6
30/01/2014	02.00	0.2	50.6
30/01/2014	03.00	0.4	50.6
30/01/2014	04.00	0.4	50.6
30/01/2014	05.00	0	50.6
31/01/2014	13.00	0	50.7
31/01/2014	14.00	1	50.7
31/01/2014	15.00	1.4	50.8
31/01/2014	16.00	2.7	50.7
31/01/2014	17.00	2.5	50.7
31/01/2014	18.00	2.7	50.7
31/01/2014	19.00	0.8	50.7
31/01/2014	20.00	0.2	50.7
31/01/2014	21.00	0	50.7
31/01/2014	22.00	0.8	50.7
31/01/2014	23.00	0.8	50.7
31/01/2014	24.00	0	50.7
01/02/2014	01.00	0.2	50.6
01/02/2014	02.00	2.7	50.7
01/02/2014	03.00	4.5	50.7
01/02/2014	04.00	0.2	50.6
01/02/2014	05.00	0	50.6
04/02/2014	20.00	0	50.5
04/02/2014	21.00	0.2	50.5
04/02/2014	22.00	0	50.4
04/02/2014	23.00	1.9	50.4
04/02/2014	24.00	1.4	50.4
05/02/2014	01.00	2.7	50.5

Date	Time (24hrs)	Rainfall (mm)	soil moisture (%v/v)
05/02/2014	02.00	2.3	50.6
05/02/2014	03.00	2.1	50.6
05/02/2014	04.00	0.6	50.6
05/02/2014	05.00	0	50.6
05/02/2014	06.00	0.6	50.6
05/02/2014	07.00	0.2	50.5
05/02/2014	08.00	0.2	50.5
05/02/2014	09.00	0	50.6
05/02/2014	12.00	0	50.5
05/02/2014	13.00	0.6	50.5
05/02/2014	14.00	1.2	50.5
05/02/2014	15.00	0.4	50.5
05/02/2014	16.00	1.9	50.5
05/02/2014	17.00	0.2	50.5
05/02/2014	18.00	0.2	50.5
05/02/2014	19.00	0.2	50.5
05/02/2014	20.00	0.2	50.5
05/02/2014	21.00	0	50.5
06/02/2014	11.00	0	50.5
06/02/2014	12.00	0.6	50.6
06/02/2014	13.00	0.8	50.6
06/02/2014	14.00	1.2	50.6
06/02/2014	15.00	1.6	50.6
06/02/2014	16.00	2.5	50.6
06/02/2014	17.00	1.4	50.5
06/02/2014	18.00	1	50.5
06/02/2014	19.00	1.4	50.5
06/02/2014	20.00	0.2	50.5
06/02/2014	21.00	0.2	50.5
06/02/2014	22.00	0.6	50.5
06/02/2014	23.00	0	50.5
06/02/2014	24.00	0	50.5
07/02/2014	01.00	1.4	50.5
07/02/2014	02.00	2.1	50.5
07/02/2014	03.00	5.6	50.5
07/02/2014	04.00	8.5	50.5
07/02/2014	05.00	3.9	50.5
07/02/2014	06.00	0.4	50.5
07/02/2014	07.00	0.4	50.5
07/02/2014	08.00	0.6	50.5

Date	Time (24hrs)	Rainfall (mm)	soil moisture (%v/v)
07/02/2014	09.00	0.4	50.5
07/02/2014	10.00	0	50.5
07/02/2014	11.00	0.2	50.5
07/02/2014	12.00	0	50.5
07/02/2014	19.00	0	50.5
07/02/2014	20.00	2.1	50.5
07/02/2014	21.00	0.2	50.5
07/02/2014	22.00	0	50.5
07/02/2014	23.00	0.2	50.5
07/02/2014	24.00	0.4	50.5
08/02/2014	01.00	1.6	50.5
08/02/2014	02.00	1	50.4
08/02/2014	03.00	0.6	50.4
08/02/2014	04.00	0	50.4
08/02/2014	05.00	2.1	50.4
08/02/2014	06.00	0.2	50.4
08/02/2014	07.00	0	50.4
08/02/2014	08.00	0	50.4
08/02/2014	09.00	0	50.4
08/02/2014	10.00	0.6	50.4
08/02/2014	11.00	0.2	50.4
08/02/2014	12.00	0	50.4
08/02/2014	13.00	0	50.4
08/02/2014	14.00	0.8	50.4
08/02/2014	15.00	0.2	50.4
08/02/2014	16.00	0	50.3
08/02/2014	17.00	0	50.3
08/02/2014	18.00	0.2	50.3
08/02/2014	19.00	0	50.3
11/02/2014	06.00	0	50.4
11/02/2014	07.00	0.2	50.4
11/02/2014	08.00	0.2	50.4
11/02/2014	09.00	0.2	50.4
11/02/2014	10.00	0.2	50.4
11/02/2014	11.00	1.2	50.4
11/02/2014	12.00	2.1	50.4
11/02/2014	13.00	0	50.4
12/02/2014	11.00	0	50.3
12/02/2014	12.00	0.2	50.3

Date	Time (24hrs)	Rainfall (mm)	soil moisture (%v/v)
12/02/2014	13.00	0.4	50.3
12/02/2014	14.00	5.2	50.5
12/02/2014	15.00	2.1	50.5
12/02/2014	16.00	0	50.5
12/02/2014	17.00	0.2	50.5
12/02/2014	18.00	0	50.5
12/02/2014	19.00	0.2	50.5
12/02/2014	20.00	0	50.5
14/02/2014	09.00	0	50.4
14/02/2014	10.00	0.6	50.4
14/02/2014	11.00	0.6	50.4
14/02/2014	12.00	0.8	50.4
14/02/2014	13.00	1	50.4
14/02/2014	14.00	1.9	50.4
14/02/2014	15.00	2.9	50.4
14/02/2014	16.00	0.4	50.4
14/02/2014	17.00	0.2	50.4
14/02/2014	18.00	0.6	50.4
14/02/2014	19.00	0.8	50.3
14/02/2014	20.00	0	50.3
14/02/2014	21.00	1	50.3
14/02/2014	22.00	0.6	50.3
14/02/2014	23.00	0.6	50.3
14/02/2014	24.00	0.2	50.3
15/02/2014	01.00	0	50.3

July 2015 Event

Date	Time	Rainfall	Mean volumetric soil moisture (%v/v)
16/07/2015	01.00	0	16.9
16/07/2015	02.00	0	16.9
16/07/2015	03.00	0	16.9
16/07/2015	04.00	0	16.9
16/07/2015	05.00	0	16.9
16/07/2015	06.00	0	16.8
16/07/2015	07.00	0	16.8
16/07/2015	08.00	0	16.8
16/07/2015	09.00	0	16.8
16/07/2015	10.00	0	16.8
16/07/2015	11.00	0	16.7
16/07/2015	12.00	0	16.7
16/07/2015	13.00	0	16.7
16/07/2015	14.00	0	16.6
16/07/2015	15.00	0	16.6
16/07/2015	16.00	0	16.6
16/07/2015	17.00	0	16.6
16/07/2015	18.00	0	16.6
16/07/2015	19.00	0	16.6
16/07/2015	20.00	0	16.6
16/07/2015	21.00	0	16.6
16/07/2015	22.00	3.1	16.9
16/07/2015	23.00	10.5	24.9
16/07/2015	24.00	14.8	34.2
17/07/2015	01.00	28.7	44.8
17/07/2015	02.00	0	36.5
17/07/2015	03.00	0	34.4
17/07/2015	04.00	0	33.4
17/07/2015	05.00	0	32.9
17/07/2015	06.00	0	32.4
17/07/2015	07.00	0	32
17/07/2015	08.00	0	31.7
17/07/2015	09.00	0	31.5
17/07/2015	10.00	0	31.2
17/07/2015	11.00	0	31
17/07/2015	12.00	0	30.8
17/07/2015	13.00	0	30.5
17/07/2015	14.00	0	30.4
17/07/2015	15.00	0	30.3
17/07/2015	16.00	0	30.1
17/07/2015	17.00	0	30
17/07/2015	18.00	0	29.9
17/07/2015	19.00	0	29.8
17/07/2015	20.00	0	29.7
17/07/2015	21.00	0	29.7
17/07/2015	22.00	0	29.6
17/07/2015	23.00	0	29.6
17/07/2015	24.00	0	29.5

Appendix 2

Figure A2 Catchment topography for Leyton Road catchment