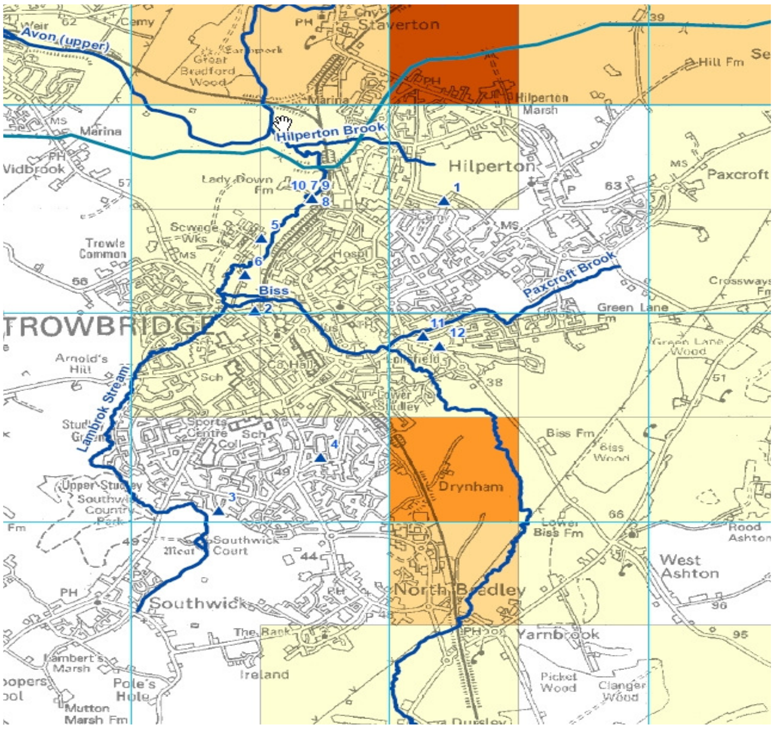
Trowbridge Surface Water Management Plan

Intermediate Assessment of Groundwater Flooding Susceptibility

Phase 2

November 2011



Prepared for

Wiltshire Council

Where everybody matters

Revision Schedule

Trowbridge Surface Water Management Plan – Intermediate Assessment of Groundwater Flooding Susceptibility
November 2011

Rev	Date	Details	Prepared by	Reviewed by	Approved by
01	14/03/2011	Draft	**Ryan Cox** Hydrogeologist	**Stephen Cox** Senior Hydrogeologist	
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Abbreviations

ACRONYM	DEFINITION
AStGWF	Areas Susceptible to Groundwater Flooding
BGS	British Geological Survey
DEFRA	Department for Environment, Fisheries and Rural Affairs
EA	Environment Agency
RBMP	River Basement Management Plan
SFRA	Strategic Flood Risk Assessment
SuDS	Sustainable Drainage Systems
SWMP	Surface Water Management Plan

Glossary

TERM	DEFINITION
Aquiclude	Formations that may be sufficiently porous to hold water, but do not allow water to move through them.
Aquifer	Layers of rock sufficiently porous to hold water and permeable enough to allow water to flow through them in quantities that are suitable for water supply.
Aquitard	Formations that permit water to move through them, but at much lower rates than through the adjoining aquifers.
Climate Change	Long term variations in global temperature and weather patterns, caused by natural and human actions.
Flood defence	Infrastructure used to protect an area against floods, such as floodwalls and embankments; they are designed to a specific standard of protection (design standard).
Floods and Water Management Act	Legislation constituting part of the UK Government's response to Sir Michael Pitt's Report on the Summer 2007 floods, the aim of which is to help protect ourselves better from flooding, to manage water more sustainably and to improve services to the public.
Fluvial flooding	Flooding by a river or a watercourse.
Groundwater	Water that is underground. For the purposes of this study, it refers to water in the saturated zone below the water table.
Interfluve	A ridge or area of land dividing two river valleys.
Pluvial Flooding	Flooding as a result of high intensity rainfall when water is ponding or flowing over the ground surface before it enters the underground drainage network or watercourse, or cannot enter it because the network is full to capacity.
Risk	The product of the probability and consequence of the occurrence of an event.
Sewer flooding	Flooding caused by a blockage, under capacity or overflowing of a sewer or urban drainage system.
Sustainable Drainage Systems	Methods of management practices and control structures that are designed to drain surface water in a more sustainable manner than some conventional techniques. The current study refers to the 'infiltration' category of sustainable drainage systems e.g. soakaways, permeable paving.

1 Introduction

1.1 Groundwater Flooding

Groundwater flooding occurs as a result of water rising up from the underlying aquifer or from water flowing from springs. This tends to occur after long periods of sustained high rainfall, and the areas at most risk are often low-lying where the water table is more likely to be at shallow depth. Groundwater flooding is known to occur in areas underlain by principal aquifers, although increasingly it is also being associated with more localised floodplain sands and gravels.

Groundwater flooding tends to occur sporadically in both location and time, and tends to last longer than fluvial, pluvial or sewer flooding. Basements and tunnels can flood, buried services may be damaged, and storm sewers may become ineffective, exacerbating the risk of surface water flooding. Groundwater flooding can also lead to the inundation of farmland, roads, commercial, residential and amenity areas.

It is also important to consider the impact of groundwater level conditions on other types of flooding e.g. fluvial, pluvial and sewer. High groundwater level conditions may not lead to widespread groundwater flooding. However, they have the potential to exacerbate the risk of pluvial and fluvial flooding by reducing rainfall infiltration capacity, and to increase the risk of sewer flooding through sewer / groundwater interactions.

The need to improve the management of groundwater flood risk in the UK was identified through Defra's Making Space for Water strategy. The review of the July 2007 floods undertaken by Sir Michael Pitt highlighted that at the time no organisation had responsibility for groundwater flooding. The Flood and Water Management Act identified new statutory responsibilities for managing groundwater flood risk, in addition to other sources of flooding and has a significant component which addresses groundwater flooding.

1.2 The Current Report

Wiltshire Council has commissioned Scott Wilson to complete Phases 1 and 2 of their Surface Water Management Plan (SWMP). A SWMP is a plan which outlines the preferred surface water management strategy in a given location. In this context surface water flooding describes flooding from sewers, drains, groundwater, and run-off from land, small water courses and ditches that occurs as a result of heavy rainfall (DEFRA, March 2010).

The current report provides an intermediate assessment of groundwater flooding susceptibility as part of the SWMP Phase 2, and provides recommendations for Phase 3. The following sections outline the geology and hydrogeology in the Trowbridge study area. From this analysis,

- Potential groundwater flooding mechanisms are identified;
- Evidence for groundwater flooding is discussed;
- Areas susceptible to groundwater flooding are recognised; and
- Recommendations are provided for further investigation.

2 Topography, Geology and Hydrogeology

2.1 Topography and Hydrology

The Bristol Avon rises in the Cotswolds and is the major river in the Trowbridge area. The Bristol Avon flows east to west, just north of Trowbridge, towards Bath and then to its outlet on the Bristol Channel. The Kennet and Avon Canal also runs adjacent to the Bristol Avon.

The River Biss flows south to north through the centre of Trowbridge towards a confluence with the Bristol Avon. It is joined by four main tributaries in the study area; the Lambrok Stream, Paxcroft Brook and an unnamed stream, close to the centre of Trowbridge; the Hilperton Brook to the north of Trowbridge. The Bristol Avon, Bitham Brook and tributaries are shown on Figure 1.

Ground levels in the Bitham Brook valley are approximately 40 maOD to the south of the study area, lowering northwards towards the Bristol Avon floodplain, where they are around 29 maOD. Ground levels are higher in the influve areas; 95 maOD in West Ashton and 60 maOD between Upper and Lower Studley in Trowbridge.

2.2 Geology

Figure 1 provides geological information for Trowbridge and the surrounding area from the British Geological Survey (BGS) 1:50,000 scale geological series. Figure 2 provides a geological cross section which has been used to improve the conceptual understanding of the area. 44 borehole logs were obtained from the BGS to provide local data and their locations are shown in Figure 1.

2.2.1 Bedrock Geology

Within the Trowbridge study area, the bedrock geology of interest comprises the Blisworth Limestone Formation[1], which in turn is overlain by the Forest Marble Formation, Cornbrash Formation, Kellaways Formation (including Kellaways Clay Member), Oxford Clay Formation, Hazelbury Bryan Formation, Newton Clay Member and Coral Rag Formation. Additional details are provided in Table 1.

There is geological faulting in the Trowbridge area as shown by Figure 1. The Trowbridge Fault is laterally extensive and runs from the south west (near to Wingfield) to the north east of Trowbridge (near Littleton). The faulting has caused the geology to the south east of Trowbridge to be downthrown and consequently the outcropping geology on either side of the Trowbridge Fault is different.

To the north west of the Trowbridge Fault the Kellaways Formation and the Cornbrash Formation are exposed over the majority of the area of interest. The BGS geological data presented on Figure 1 has subdivided the Kellaways Formation to show the Kellaways Clay Member (mudstone), which is located in the north of the study area. In the north west corner of the study area the Forest Marble Formation and the Blisworth Limestone Formation outcrop. These Formations have a syncline structure as shown by Figure 2. The base of the Blisworth Limestone Formation and the underlying Fullers Earth are not known and consequently are not depicted on Figure 2.

[1] Previously referred to as the Great Oolite Limestone

To the south east of the Trowbridge Fault the geology has been downthrown exposing the Oxford Clay at surface. The thickness of the Oxford Clay close to the Trowbridge Fault is unclear, although the geological log for borehole ST85NE2 suggests that it is around 130 m (Figure 2).

Further south east on higher ground near West Ashton, the Oxford Clay is overlain by the Hazelbury Bryan Formation (sub divided into sandstone and mudstone members), Newton Clay Member (sandy mudstone) and Coral Rag Formation (ooidal limestone).

Table 1 Bedrock geology of significance to the study

Geological Units		Description	Thickness*
Corallian Group	Coral Rag Formation	Ooidal Limestone	25 to 35 m
	Newton Clay Member	Sandy mudstone	
	Hazelbury Bryan Fm (Previously Lower Calcareous Grit),	Sub divided into sandstone and mudstone horizons	
Ancholme Group	Oxford Clay Formation	Mudstone	Up to 150 m
	Kellaways Formation (Kellaway Clay Member)	Mudstone / Sandy Mudstone	Up to 28 m
Great Oolite Group	Cornbrash Formation	Fine grained shelly limestone with thin clays and marls. Typically rubbly at the base but more sandy and better bedded in the upper part.	Up to 5 m
	Forest Marble Formation	Clay with impersistent band of shelly limestone. Acton Turville Beds (mainly limestone) at base	Up to 35 m
	Blisworth Limestone Formation	Limestone	20 to 30 m
	Fullers Earth (grouped for simplicity)	Clay with chalky white limestone and Fullers Earth Rock beds	5 to 15 m

*Thickness from The properties for secondary aquifers in England and Wales (Jones et al., 2000), Table 6.6 page 91.

2.2.2 Superficial Geology

The superficial geology within the area of interest consists of Alluvium, Head and River Terrace Deposits.

In the majority of the study area, superficial geology is not present. However, in the northern reaches of the study area in the valley of the Bristol Avon River, there are significant River Terrace Deposits (sand and gravel).

Within the valley floor of the River Biss and its un-named tributary there are deposits of Alluvium (clay, silt, sand & gravel). Boreholes ST85NE77, ST85NE76 and ST85NE106 indicate that the thickness of Alluvium in Trowbridge town centre is around 2.1 – 3.5 m (see Figure 1 for locations). The logs suggest that the in this area the proportions of clay, silt, sand & gravel are variable.

To the south east, west and north of Trowbridge there are also deposits of Head, which comprise a mixture of clay, silt, sand & gravel. The most significant deposits within the study area are those close to Drynham and Staverton / Hilperton Marsh. The borehole logs ST86SE35 & ST85NE31 suggest that the Head deposits are around 0.6 -1.3 m thick and consist of slightly silty sandy clay (with made ground at surface).

2.3 Hydrogeology

The hydrogeological significance of the various geological units within the study area is provided in Table 2. The range of permeability likely to be encountered for each geological unit is also incorporated in Table 2 and is shown in Figure 3.

Table 2: Geological Units in the Study Area and their Hydrogeological Significance

Geological Units		Expected Permeability Based on geological data	Hydrogeological Significance
Superficial Geology	River Terrace Deposits (Sand & Gravel)	High	Secondary A aquifer
	Head Deposits	Low to Moderate	Variable (probably an aquitard but may locally form a secondary aquifer)
	Alluvium	Low to Moderate	Variable but classified as Secondary aquifer
Bedrock Geology	Coral Rag Formation	Moderate to High	Secondary A aquifer
	Newton Clay Member	Low	Aquiclude
	Hazelbury Bryan Fm (sandstone) Hazelbury Bryan Fm (mudstone)	Moderate to High Low	Secondary A aquifer Aquiclude
	Oxford Clay Formation	Low	Aquiclude
	Kellaways Formation	Low to Moderate	Aquitard
	Kellaways Clay Member	Low	Aquiclude
	Cornbrash Formation	Moderate to High	Secondary A aquifer
	Forest Marble Formation – Mudstone Forest Marble Formation - Limestone	Low to Moderate Moderate to High	Classified as principal aquifer but generally lower horizon is more permeable.
	Blisworth Limestone Formation	High	Principal aquifer
	Fullers Earth (grouped for simplicity)	Low to Moderate	Variable but classified as Secondary aquifer

'Principal Aquifer' - layers that have high permeability. They may support water supply and/or river base flow on a strategic scale.
'Secondary Aquifer (A)' - permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.

2.3.1 Bedrock Geology

The Oxford Clay Formation, Hazelbury Bryan Formation (mudstone) and Newton Clay Member are aquicludes and do not permit groundwater flow. The Environment Agency has classified these units as unproductive strata (Environment Agency website).

The BGS mapping indicates that the Kellaways Formation has a higher sand content than the Kellaway Clay Member, which is considered to behave as an aquiclude. The Environment Agency does not classify the Kellaways Formation as productive strata, and borehole log ST85NW10 indicates high clay content for the full thickness of the unit, Therefore, the Formation is assumed to behave as an aquitard for the purpose of this study.

The Hazelbury Bryan Formation (sandstone) and Coral Rag Formation are classified as aquifers (water bearing) and sit above the impermeable Oxford Clay Formation. The two units are separated by the Newton Clay Member aquiclude. These aquifers are of interest in the south east of the study area where they outcrop at surface.

The properties for primary aquifers in England and Wales (Jones et al., 1997) considers the Forest Marble Formation in this region to be a principal aquifer. The Formation has a lower permeability in the upper horizon due to a higher clay content, although the basal horizon is generally limestone facies, which are water bearing. Due to the structural geology and the River Biss, this unit has a small outcrop in the centre of Trowbridge and also in the north west corner of the study area. Therefore, the Forest Marble Formation is of some interest to the study.

The Cornbrash Formation is classified as a secondary A aquifer (water bearing) and rests above the Forest Marble Formation. The thin aquifer is expected to be hydraulically separated from the underlying Blisworth Limestone Formation (Table 1) by the clays in the Forest Marble Formation. This should allow for the development of a perched water table in the Cornbrash Formation. The Cornbrash Formation is of interest to this study because it has a significant outcrop area within the study area.

The Blisworth Limestone Formation underlies the Forest Marble Formation and is classified as a principal aquifer. The Forest Marble Formation confines the Blisworth Limestone aquifer in the Trowbridge area and therefore the aquifer is not pertinent to the current study.

2.3.2 Superficial Geology

The hydrogeological significance of the Alluvium in the river valleys is expected to be variable, although locally it may behave as an aquifer where the sand and gravel content is high. Borehole logs ST85NE77, ST85NE76 and ST85NE106 suggest that there is a perched water table within this unit in the Trowbridge area and so it is of interest to the current study.

Head deposits are expected to behave as an aquitard, although sand horizons may locally form a secondary aquifer depending on their lateral extent and thickness. Head deposits are of interest to the study in the localities where they are present.

The sand and gravel River Terrace Deposits are expected to behave as a secondary aquifer and are of interest in the northern reaches of the study area where they are present.

2.3.3 Bedrock Groundwater Levels

Cornbrash Formation

There is no monitoring undertaken by the Environment Agency in the Cornbrash Formation. In addition, the majority of the borehole logs obtained from the BGS do not contain water level data for the Cornbrash Formation. Nonetheless, Table 3 does present water level data / comments for three borehole logs. Whilst it is important to note that the data is not current and does not show seasonal fluctuations, it does suggest that a perched water table may exist at some localities. The locations of the boreholes identified within Table 3 are shown on Figure 1.

Table 3: BGS Borehole Logs - Water level Comments for the Cornbrash Formation

Borehole Name	Approximate Location	Water Level (mbgl)	Date of record	Base of Cornbrash below GL (m)
ST85NE1	Hilperton	No water level data – log comments surface geology is Cornbrash and stream present	N/a	<2
ST85NW29	Widbrook	1.8 – 1.43	08/1987	3.43
ST85NW24	Widbrook Bridge	'No water'	1983	2.6

'mbgl' – meters below ground level.
'GL' – Ground Level.

Forest Marble Formation

There is no groundwater level monitoring undertaken by the Environment Agency in the Forest Marble Formation. Whilst the lower Forest Marble Formation may be water bearing, development of groundwater resources appears to have targeted the deeper and more permeable Blisworth Limestone Formation.

Blisworth Limestone Formation

Groundwater level data for one borehole has been obtained from the Environmental Agency for the Trowbridge area. The borehole, referred to as Hilperton No 1, is located at Hilperton (Figure 1) and the water level data are provided in Appendix 1. The water level record shows that:

- Season fluctuations in the Blisworth Limestone Formation (near to Hilperton) range between 2.5 and 7.5 metres; and
- The piezometric water level in the Blisworth Limestone Formation is at significant depth below ground level in the Hilperton area. The highest water levels were recorded in 1982 (7.5 metres below ground level), although in recent years maximum piezometric water levels have been around 15 metres below ground level.

Piezometric water levels within the Blisworth Limestone Formation may be closer to ground level in other parts of the study area. However, the overlying clay horizons in the Forest Marble Formation are expected to prevent groundwater flooding from this aquifer.

2.3.4 Superficial Deposit Groundwater Levels

The Environment Agency does not monitor groundwater levels in the superficial deposits. However, four borehole logs collated from the BGS (Table 4) indicate that the water level in the Alluvium ranges between 2.8 and 6.6 metres below ground level in the centre of Trowbridge. Whilst there are no recent water level data, it would appear that in certain locations the Alluvium forms a perched aquifer over the bedrock geology.

Table 4: BGS Borehole Logs - Water level Comments for the Alluvium

Borehole Name	Water Level (mbgl)	Water Level (mAOD)	Date of record	Base of Alluvium
ST85NE12	6.4 – 6.6	Unknown	06/1976	6.5
ST85NE13	2.8	Unknown	Unknown	3.9
ST85NE106	4	32.17	11/1991	5.4
ST85NE76	4.45	Unknown	06/1994	4.9

'mbgl' – meters below ground level

2.3.5 Hydraulic Relationships

Surface Water / Groundwater Interactions

River flow and stage data were requested from the Environment Agency and the locations of gauging stations are shown of Figure 4.

The Trowbridge gauging station monitors the stage of the River Biss before it merges with the Lambroc Stream. However, the stage data cannot be used to identify the nature of any groundwater / surface water interactions, as there are no groundwater level data for the permeable outcrop geology in this area (primarily the Cornbrash Formation).

The Hawkeridge station located further upstream of the Trowbridge station measures flow in the River Biss at North Bradley (Figure 4). The data are not relevant to the current study as the River Biss is not in hydraulic continuity with the bedrock aquifers in the study area.

With regard to superficial geology groundwater / surface water interactions, it is likely that there is some hydraulic continuity between a perched water table in the River Terrace Deposits and the Bristol Avon River. There may also be groundwater / surface water interactions associated with the Alluvium and Head Deposits along the River Biss.

Unfortunately there are no continuous or recent groundwater level data for the aquifers of interest and therefore it is not possible to gain a more informed understanding of groundwater / surface water interactions.

2.3.6 Abstractions and Discharges

Groundwater and surface water abstraction and discharge data were requested from the Environment Agency. The locations of licensed discharges and minor abstractions are shown on Figure 4.

There are no major groundwater abstractions (>20 m^3/day) within the Trowbridge study area. However, there are three small groundwater abstractions (<20 m^3/day); two near Southwick and a third near West Ashtown.

2.3.7 Artificial Groundwater Recharge

Water mains leakage data for the Trowbridge area were not provided for this study. It should be noted that additional recharge to perched groundwater tables by leaking mains could result in a local rise in groundwater levels. This rise might not prove significant under dry conditions, but could exacerbate the risk of groundwater flooding following periods of heavy rainfall.

The drainage/sewer network can act as a further source of artificial recharge. When pipes are installed within principle or secondary aquifers, the groundwater and drainage network can become hydraulically connected due to leakage. When pipes are empty, groundwater may leak into the drainage network with water flowing in through cracks and porous walls, draining the aquifer and reducing groundwater levels. During periods of heavy rainfall when pipes are full, leaking pipes can act as recharge points, artificially recharging the groundwater table and subsequently increasing groundwater levels.

These groundwater level / pipe network interactions are expected to be limited to those areas where there are outcrops of Cornbrash Formation and River Terrace Gravels, and perhaps Alluvium and Head deposits (Figure 1).

3 Assessment of Groundwater Flooding Susceptibility

3.1 Groundwater Flooding Mechanisms

Based on the current hydrogeological conceptual understanding, there is potential for minor groundwater flooding in the Trowbridge study area. The key groundwater flooding mechanisms that may exist are:

- **Cornbrash Formation outcrop running south west to northeast across the study area, including central Trowbridge:** There is the potential for a perched groundwater table to exist within the Cornbrash Formation. Due to the permeable but thin nature of this Formation, basements / cellars and other underground structures may be at risk from groundwater flooding following periods of prolonged rainfall, increased utilisation of infiltration SUDs and / or artificial recharge from leaking pipes.
- **Hazelbury Bryan Formation (sandstone) and Coral Rag Formation outcrop area in the south east of the study area (West Ashton):** These two Formations are classified as aquifers and whilst there is no supporting water level data it is likely that a perched groundwater table exists within these Formations. Basements / cellars and other underground structures may be at risk from groundwater flooding following periods of prolonged rainfall, increased utilisation of SUDs and / or artificial recharge from leaking pipes.
- **Superficial geology aquifers in hydraulic continuity with the Bristol Avon River and its tributaries:** Groundwater flooding may be associated with the substantial sand and gravel River Terrace Deposits, or to a lesser degree Head and Alluvium deposits, where they are in hydraulic continuity with surface water courses. Stream levels may rise following high rainfall events but still remain “in-bank”, and this can trigger a rise in groundwater levels in the associated superficial deposits. The properties at risk from this type of groundwater flooding are probably limited to those with basements / cellars, which have been constructed within the superficial deposits.
- **Superficial aquifers not in hydraulic continuity with surface water courses:** groundwater flooding is also associated with substantial River Terrace Deposits (gravel and sand) and Head deposits, but occurs where they are not hydraulically connected to surface water courses. Perched groundwater tables can exist within these deposits, developed through a combination of natural rainfall recharge and artificial recharge e.g. leaking water mains. The properties at risk from this type of groundwater flooding are probably limited to those with basements / cellars.
- **Impermeable (silt and clay) areas downslope of aquifers in various locations:** Groundwater flooding may occur where groundwater springs / seepages form minor flows and ponding over impermeable strata where there is poor drainage. This mechanism may occur as a result of natural (e.g. rainfall) or artificial (e.g. water main leakage) recharge.
- **Made ground in various locations:** a final mechanism for groundwater flooding may occur where the ground has been artificially modified to a significant degree. If this ‘made ground’ is of substantial thickness and permeability, then a shallow perched water table may exist. This could potentially result in groundwater flooding at properties with basements, or may equally be considered a drainage issue.

3.2 Evidence of Groundwater Flooding

There are no reported groundwater flooding incidents within the study area However, other sources of flooding have been identified and the locations of historic flood incidents are shown on Figures 1, 3, 4 and 5 and details are provided in Table 5. It is possible that some of these incidents were influenced by groundwater conditions, although there are no available data to confirm this.

Table 5: Historic Flooding Incidents within the Study Area.

Bedrock Geological Units*	Superficial Deposits*	Grid Reference	No**	Reported Incident	Date
Cornbrash Fm	None	159084 386421	1	Sewer - 2 in 10 years	09/01/2007
Cornbrash Fm	None	158024 384954	2	Sewer - 2 in 10 years	09/01/2007
Kellaways Fm	None	156104 384675	3	Sewer - 2 in 10 years	09/01/2007
Oxford Clay Fm	None	156616 385466	4	Sewer - 2 in 10 years	09/01/2007
Kellaways Fm	Alluvium	158720385006	5	Sewage Treatment Works, pumping stopped for a while	12/05/1960
Kellaways Fm	Alluvium	158370 384880	6	Fluvial - Ladydown Mill, Trowbridge up to confluence with the Lambrok Stream. No further details.	12/04/1960
Kellaways Fm	Alluvium	159100 385400	7		07/10/1968
Kellaways Fm	Alluvium	159100 385400	8		01/01/1991
Kellaways Fm	Alluvium	159100 385400	9		01/01/1991
Kellaways Fm	Alluvium	159100 385400	10		01/01/1991
Oxford Clay Fm	None	157780 386258	11	Sewer - 2 in 10 years	09/01/2007
Oxford Clay Fm	None	157687 386386	12	Sewer - 2 in 10 years	09/01/2007

3.3 Areas Susceptible to Groundwater Flooding

The Environment Agency has produced a data set referred to as 'Areas Susceptible to Groundwater Flooding (AStGWF)', on a 1 km grid (Figure 5). This utilises the BGS 1:50,000 Groundwater Flood Susceptibility data set for consolidated aquifers (bedrock) and superficial geology.

The Environment Agency data set shows the percentage of each 1 km square that falls within the high to very high BGS groundwater flooding susceptibility categories. It does not show the probability / risk of groundwater flooding occurring; this can only be determined following site specific investigation works and desk studies. It also does not take into account groundwater level rebound following cessation of abstraction.

An absence of values for any grid square means that no part of that square is identified as being susceptible to groundwater emergence (Environment Agency AStGWF Guidance Document).

The areas that are identified as being most susceptible to groundwater flooding are located close to the Upper Bristol Avon River in the north of the study area, or close to the River Biss in the south of the study area (Drynham / North Bradley). By comparing the data with Figure 1 (geological map) it is apparent that the areas susceptible to groundwater flooding are those where significant superficial deposits are present, particularly River Terrace Deposits.

It is interesting to note that many of the grid squares representing outcrops of Cornbrash Formation (e.g. Hilperton), Hazelbury Bryan Formation and Coral Rag Formation (West Ashton) have not been identified as areas susceptible to groundwater flooding. This may reflect the lack of water level data available to the BGS when creating the original Groundwater Flood Susceptibility Map. This notwithstanding, it is thought that the approximate areas identified by the Environment Agency as being susceptible to groundwater flooding are sensible.

3.4 Importance of Long Term Groundwater Level Monitoring

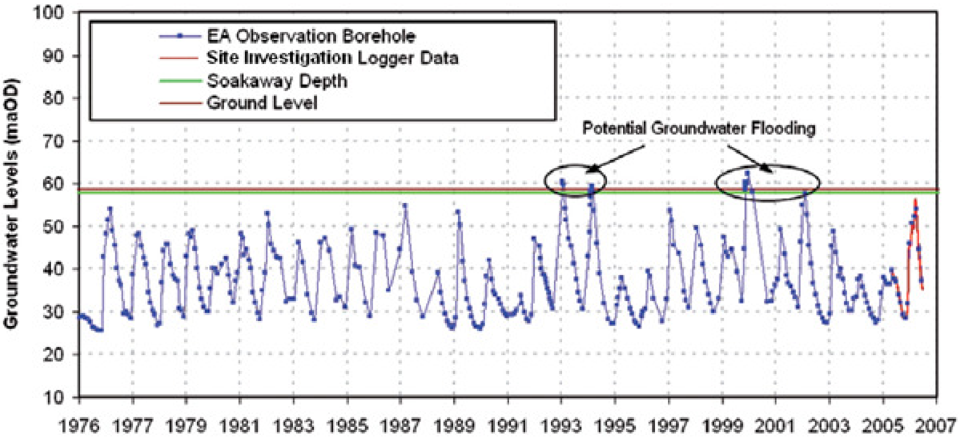
Groundwater flow direction, depth to groundwater, topography and the degree of artificial influence in the subsurface (e.g. leaking water mains or groundwater abstractions) play an important role when considering the susceptibly of an area to groundwater flooding. Unfortunately groundwater level data for the superficial aquifers is limited to recorded water strikes or rest water levels on BGS borehole logs, which only provide groundwater levels at one location and for one point in time. Without long term groundwater monitoring, it is not possible to derive groundwater level contours, or understand maximum seasonal fluctuations. Therefore it is not possible to provide a detailed assessment of groundwater flood risk or provide detailed advice on suitability for infiltration SUDS.

It is not sufficient to rely on the work undertaken by developers through the planning application process, unless long term monitoring (several years) is one of the conditions when granting planning permission. Groundwater levels are often only measured once, or, at most, for a number of weeks. It would be advisable for the Council, in combination with the Environment Agency, to begin long term monitoring of the Cornbrash Formation and River Terrace Deposit groundwater levels. This data would also be useful for understanding groundwater / surface water interactions, which is important when considering the design of fluvial flood defences.

It is also important to understand how changing policies relating to infiltration SUDS can impact groundwater levels. For example the introduction of infiltration SUDS (e.g. soakaways) may cause a rise in peak groundwater levels. This could prevent soakaways from operating and the reduction in unsaturated zone thickness may not be acceptable to the Environment Agency owing to its responsibilities under the Water Framework Directive.

Long term groundwater level monitoring is required to support decision making with respect to future land development and future co-ordinated investments to reduce the risk and informing the assessment of suitability for infiltration SUDS.

Schematic demonstrating the importance of long term groundwater level monitoring



4 Water Framework Directive and Infiltration SUDS

The Water Framework Directive approach to implementing its various environmental objectives is based on River Basin Management Plans (RBMP). These documents were published by the Environment Agency in December 2009 and they outline measures that are required by all sectors impacting the water environment. The Thames River Basin District is considered within the current study since infiltration Sustainable Drainage Systems (SUDS) have the potential to impact the water quality and water quantity status of aquifers and surface water courses.

4.1 Current Quantity and Quality Status

The current quantitative assessment for the Bristol Avon Forest Marble aquifer (GB40902G302900) is ‘poor’ but the current quality assessment is ‘good’. The quantitative assessment in 2015 is predicted to remain as poor due to a poor resource balance. However, the chemical quality in 2015 is predicted to remain as ‘good’. The current overall status is classified as ‘poor’ but the status objective is to have ‘Good Quantitative Status by 2027, Good Chemical Status by 2015’.

The RBMPs only consider the quantitative and quality assessment for the Bristol Avon Forest Marble aquifer in the Trowbridge study area. There is no assessment for the Cornbrash Formation, Hazelbury Bryan Formation or Coral Rag Formation in the study area.

4.2 Infiltration SUDS Suitability

Improper use of infiltration SUDS could lead to contamination of the superficial or bedrock geology aquifers, leading to deterioration in aquifer quality status or groundwater flooding / drainage issues. However, correct use of infiltration SUDS is likely to help improve aquifer quality status and reduce overall flood risk.

Environment Agency guidance on infiltration SUDS is available on their website at: http://www.environment-agency.gov.uk/business/sectors/36998.aspx. This should be considered by developers and their contractors, and by Wiltshire Council when approving or rejecting planning applications.

The areas that may be suitable for infiltration SUDS (e.g. soakaways, permeable paving) exist where there is a combination of higher ground (interfluves) and permeable geology (see Figure 3). For example, although the River Terrace Deposits to the north of the study area are expected to be permeable, they are close to a major surface water course and the depth to groundwater may be unsuitable for infiltration SUDS.

Consideration should also be given to the impact of increased infiltration SUDS on properties further down gradient. An increase in infiltration / groundwater recharge will lead to an increase in groundwater levels, thereby increasing the susceptibility to groundwater flooding at the down gradient location. This type of analysis is beyond the scope of the current report.

Restrictions on the use of infiltration SUDS apply to those areas within Source Protection Zones (SPZ), which are shown on Figure 3. However, Figure 3 shows that currently there are no SPZs in the Trowbridge study area.

5 Conclusions and Recommendations

5.1 Conclusions

The following conclusions can be drawn from the current study:

- The clays of the Forest Marble Formation are expected to hydraulically separate the underlying Blisworth Limestone Formation principal aquifer from the surface aquifers. Therefore, the Blisworth Limestone Formation is not of key interest to the groundwater flooding assessment.
- The key areas of interest are those underlain by the Cornbrash Formation, Hazelbury Bryan or River Terrace Deposits (Figure 1). These geological units are expected to behave as aquifers and are likely to contain perched water tables i.e. they are a potential source of groundwater flooding. Where Alluvium and Head deposits exist, these may also contain perched water tables.
- A number of potential groundwater flooding mechanisms have been identified. Key mechanisms are (i) rapid water level fluctuations in the River Terrace Deposits (Bristol Avon River) and Alluvium / Head deposits (River Biss) in response to river stage fluctuations, and (ii) response of perched groundwater levels within the Cornbrash Formation and Hazelbury Bryan Formation to increased use of infiltration SUDS, leaking pipes and barriers to groundwater flow such as sheet piling. Properties at greatest risk of flooding are those with basements / cellars.
- Based on the available flood incident data and Environment Agency 'Areas Susceptible to Groundwater Flooding' data set, the areas most susceptible to groundwater flooding are those associated with River Terrace Deposits (close to the Bristol Avon) or Alluvium / Head deposits (River Biss).
- The lack of reported groundwater flooding incidents suggests that whilst a perched aquifers may exist, groundwater levels are sufficiently low and/or there are a lack of receptors (e.g. basements), such that groundwater flooding has not been an issue. However, it is important to note that increased discharges to these aquifers through infiltration SUDs may lead to future groundwater flooding issues. Therefore, use of infiltration SUDs should be carefully managed.
- The Environment Agency and Council do not currently monitor groundwater levels in the aquifers that outcrop in this area. Without long term groundwater monitoring, it is not possible to derive groundwater level contours or understand maximum seasonal fluctuations and potential climate change impacts. Therefore, at this stage, it is not possible to provide a detailed assessment of groundwater flood risk or provide detailed advice on suitability for infiltration SUDS.

5.2 Recommendations

The following recommendations are made based on the current draft report:

- Data identifying properties with basements / cellars should be collected by Wiltshire Council;
- Site investigation reports for historic development sites could be reviewed to obtain additional groundwater level information, to improve the conceptual understanding of the area;
- The areas identified as being susceptible to groundwater flooding should be compared with those areas identified as being susceptible to other sources of flooding e.g. fluvial, pluvial and sewer. An integrated understanding of flood risk will be gained through this exercise;
- Pluvial modelling often assumes that no infiltration of rainfall occurs (a worst case scenario). It is recommended that a sensitivity analysis is undertaken, whereby infiltration is modelled in those areas where permeable superficial geology are located;
- Monitoring boreholes should be installed in the River Terrace Deposits, Cornbrash Formation and Hazelbury Bryan fitted with automatic level recording equipment for a period of one year and water quality sampling undertaken. At this point a review of the monitoring network should be undertaken and an update on infiltration SUDS guidance provided.
- The impact of infiltration SUDS on water quality and quantity with respect to the Water Framework Directive should be considered when approving planning applications;
- The impact of infiltration SUDS on groundwater levels (and therefore groundwater risk) should be considered further. This may require the construction of a local groundwater model following collection of groundwater level data.

6 References

- DEFRA, March 2010. Surface Water Management Plan Technical Guidance.
- Environment Agency, December 2009. River Basin Management Plan. Thames River Basin District (Annex B).
- Environment Agency, 2010. Areas Susceptible to Groundwater Flooding. Guidance Document
- Jones, H K, Morris, B L, Cheney, C S, Brewerton, L J, Merrin, P D, Lewis, M A, MacDonald, A M, Coleby, L M, Talbot, J C, McKenzie, A A, Bird, M J, Cunningham, J, and Robinson, V K., 2000. The physical properties of minor aquifers in England and Wales. British Geological Survey Technical Report, WD/00/4. 39pp. Environment Agency R&D Publication 68.