

Proof of Evidence
FLOOD RISK AND DRAINAGE

Appendices

Expert Witness:

[REDACTED]

Managing Director & Partner

Town and Country Planning Act 1990

Appeal Against Refusal of Planning Consent

Appeal Reference: APP/C1435/W/22/3307820 WD/2021/2198/MAO

For

Appeal for Land at Bird in Eye Farm, Framfield, Uckfield.

Prepared for

Appellant: K. Smith (Rule 6 Party)

August 2023

1 Appendices

**Appendix A.1 – Extract from the Appeal Decision from July 2023, Appeal Ref:
APP/N1920/W/23/3314268**

Appendix A.2 – Flood risk mapping from various sources

Appendix A.3 – Site context in relation to the surrounding watercourses

Appendix A.4 – Photographs of B2102/Framfield Road flooding in November 2022

Appendix A.5 – Information on rainfall gauging stations

Appendix A.6 – Historic flood information provided by ESCC

Appendix A.7 – R&D Output FD2320/TR2 and Supplementary Note

Appendix A.8 – Risk of flooding from surface water extent for Framfield Road

Appendix A.9 –Phase I Desk Study and Site Reconnaissance Report (2015)

Appendix A.10 – Extracts from relevant guidance

Appendix A.11 – Email correspondence with Stantec, dated 7th August 2023

Appendix A.1 – Extract from the Appeal Decision from July 2023, Appeal Ref: APP/N1920/W/23/3314268



Appeal Decision

Inquiry held on 3, 4, 16 and 17 May, 29 and 30 June, 5, 7, and 13 July 2023.

Site visit made on 17 May 2023.

by Joanna Gilbert MA (Hons) MTP MRTPI

an Inspector appointed by the Secretary of State

Decision date: 19 July 2023

Appeal Ref: APP/N1920/W/23/3314268

Land at Little Bushey Lane, Bushey.

- The appeal is made under section 78 of the Town and Country Planning Act 1990 against a failure to give notice within the prescribed period of a decision on an application for outline planning permission.
 - The appeal is made by Redrow Homes Limited against Hertsmere Borough Council.
 - The application Ref 22/1071/OUT, is dated 14 June 2022.
 - The development proposed is residential development (up to 310 units) with access from Little Bushey Lane, and land reserved for primary school, community facilities and mobility hub (Class E) along with car parking, drainage and earthworks to facilitate drainage, open space and all ancillary and enabling works. (Outline Application with Appearance, Landscaping, Layout and Scale Reserved).
-

Decision

1. The appeal is dismissed and planning permission for residential development (up to 310 units) with access from Little Bushey Lane, and land reserved for primary school, community facilities and mobility hub (Class E) along with car parking, drainage and earthworks to facilitate drainage, open space and all ancillary and enabling works (Outline Application with Appearance, Landscaping, Layout and Scale Reserved) is refused.

Application for costs

2. An application for costs was made by Redrow Homes Limited against Hertsmere Borough Council. This is the subject of a separate decision.

Procedural Matters

3. The planning application was in outline, with all matters reserved for subsequent approval except access. I have considered the appeal on that basis.
4. The description of development in the banner heading is taken from the appeal form as the description appears to have been amended following the planning application's submission.
5. On 17 February 2023, National Highways lifted their objection in respect of the M1 motorway, specifically regarding Junction 5's capacity and flood risk.
6. Following the appeal's submission, the Council's putative reasons for refusal were endorsed by the Council's Planning Committee on 23 February 2023.
7. Amended parameter plans and an amended Flood Risk Assessment (FRA) were produced with regard to drainage and flood risk in early March 2023. These were subject to further public consultation between 16 March and 6 April 2023. I have had regard to the responses to this consultation. No prejudice would be

caused to any parties by my consideration of these amended documents, given the extent of consultation.

8. On submission of the main parties' proofs of evidence on 5 April 2023, the Council and the Lead Local Flood Authority (LLFA) raised concerns about the absence of a sequential test (ST) in relation to all sources of flooding. Further concerns were also raised in respect of drainage. The need to undertake the ST gave rise to the Inquiry being phased across May, June and July 2023.
9. On 10 May 2023, a Statement of Common Ground (SOCG) – Flood Risk and Drainage confirmed that the only remaining area of disagreement with regard to flood risk and drainage related to the ST. This resulted in amendment of the third main issue to reflect the change in circumstances.
10. The appellant provided their ST evidence on 22 May 2023. The Council and the LLFA provided their ST rebuttals on 12 June 2023. As there were remaining areas of dispute, a further SOCG was requested but not provided until 28 June 2023. I have dealt with matters pertaining to the ST in the decision below.
11. I have had regard to a signed and executed unilateral undertaking submitted and dated 13 July 2023 and a signed and executed bilateral undertaking between the appellant and Hertfordshire County Council (HCC) submitted and dated 13 July 2023.

Main Issues

12. The site lies within the Metropolitan Green Belt. As the main parties agree that the proposed development would constitute inappropriate development in the Green Belt with regard to the National Planning Policy Framework (the Framework), the main issues in this appeal are:
 - a) The effect of the proposed development on the openness and purposes of the Green Belt;
 - b) The effect of the proposed development on the character and appearance of the area;
 - c) Whether the proposed development would be in a suitable location with regard to local and national policies relating to flood risk; and
 - d) Whether any harm to the Green Belt and any other harm, is clearly outweighed by other considerations, so as to amount to the very special circumstances necessary to justify the proposed development.

Reasons

The site and the proposed development

13. The site comprises some 18 hectares of fields used for grazing by horses. Immediately north and east, it adjoins pasture fields and the vegetated buffer separating the site from the M1 and A41 road corridor (the road corridor). Beyond the road corridor are Hilfield Park and Aldenham reservoirs, Hilfield Castle, Aldenham Country Park, and the London Elstree Aerodrome.
14. To the south-east, there are further fields with Caldecote Farm, the Niland Conference Centre, Rosary Priory Convent and Immanuel College beyond and closer to Elstree Road. To the south and west, the site adjoins Little Bushey Lane and the rear gardens of residential properties on Little Bushey Lane, The

Squirrels, and Wayside Avenue. The frontage to Little Bushey Lane is bounded by trees and hedges. West and north-west, there are further pasture fields, Hart's Farm Stables, and relatively recent residential development.

15. The fields within the site are bounded by mature native hedgerows and post and rail fencing. A number of watercourses flow across the site. There are several large, mature trees, as well as dead and fallen trees, within field boundaries or dotted sporadically across the fields.
16. The site's topography varies, with the land at the southern and western boundaries at up to 105 metres above Ordnance Datum (AOD) and land to the north of the site at around 88 metres AOD. A high-voltage power line crosses the site north to south. Two pylons are located within the field east of The Squirrels and Wayside Avenue. A gas main runs across part of the site.
17. Two public rights of way (PROW) 33 and 40 cross the site. PROW 33 travels from the site's western edge at Little Bushey Lane and runs north-eastwards towards the road corridor, while PROW 40 crosses the site from Little Bushey Lane and runs south-eastwards to the road corridor where it crosses the M1 via a footbridge towards the A41.
18. The proposed development would comprise up to 310 residential units, land for a primary school, and a community mobility hub. There would be a new vehicular access from Little Bushey Lane, as well as pedestrian and cycle access through the site with the diversion of PROW 33 and 40. The green infrastructure would include informal recreation areas, sustainable drainage features, trees and hedgerows.

Policy context

National policy

19. Chapter 13 of the Framework seeks to protect Green Belt land. Paragraph 137 of the Framework confirms that the Government attaches great importance to Green Belts. Paragraph 138 of the Framework sets out Green Belt purposes. Paragraph 147 of the Framework confirms that inappropriate development, is by definition, harmful to the Green Belt and should not be approved except for in very special circumstances. Paragraph 148 of the Framework states that when considering any planning application, local planning authorities should ensure that substantial weight is given to any harm to the Green Belt. 'Very special circumstances' will not exist unless the potential harm to the Green Belt by reason of inappropriateness, and any other harm resulting from the proposal, is clearly outweighed by other considerations.
20. Paragraph 174 of the Framework states that planning policies and decisions should contribute to and enhance the natural and local environment, including criterion b) of paragraph 174 which refers to recognising the intrinsic character and beauty of the countryside, and the wider benefits from natural capital and ecosystem services – including the economic and other benefits of the best and most versatile agricultural land, and of trees and woodland. I have dealt with elements of the Framework pertaining to flood risk below. Relevant elements of the Planning Practice Guidance (PPG) are set out within the decision.

Local policy

21. The Development Plan for Hertsmere includes the Hertsmere Local Plan Development Plan Document: Core Strategy (CS), adopted in January 2013, and the Hertsmere Local Plan: Site Allocations and Development Management Policies Plan (SADM), adopted in November 2016.
22. CS Policy SP1 deals with the creation of sustainable development. It prioritises developing brownfield land and delivering development opportunities in Borehamwood, but also expects all existing built up areas within urban settlements to accommodate opportunities for meeting local housing, jobs growth and other development needs. Amongst other things, it seeks development that ensures a safe, accessible and healthy environment; conserves and enhances biodiversity; mitigates the environmental impact of transport; avoids prejudicing, either individually or cumulatively, characteristics and features of the natural and built environment; avoids inappropriate development within the Green Belt; and avoids development in the floodplain and close to river corridors unless the requirements of the ST and exception test (ET) have been met and flood prevention/mitigation measures are in place.
23. CS Policy SP2 requires a positive approach that reflects the Framework's presumption in favour of sustainable development. CS Policy CS1 states that the Council will make provision for at least 3,990 additional dwellings between 2012 and 2027. It outlines that the SADM will factor in a range of considerations in identifying new locations for development. CS Policy CS2 prioritises locating the majority of residential development in Borehamwood, Potters Bar and Bushey, with up to 25% of new housing in Bushey.
24. CS Policy CS3 confirms that where housing delivery has fallen below the required minimum rate over a rolling three year period by at least 20% and at the same point in time the expected completions over the following five years will be insufficient to compensate for the shortfall of the minimum required annualised rate, a review of housing allocations will be undertaken including consideration of safeguarded land for housing and land presently designated as Green Belt. New housing development will only be permitted if satisfactory arrangements are in place to provide the necessary infrastructure.
25. Aiming to increase the supply of affordable housing, CS Policy CS4 states that developments of five self-contained, residential units or more (gross), or residential sites of more than 0.2 hectares, should make provision for affordable housing. On sites of 15 units or more, a mix of social rented housing, affordable rent and intermediate housing will be required, with the precise tenure and dwelling mix to be agreed by the Council. At least 35% affordable housing is sought in the appeal location. The policy's aims equate to an affordable housing target of 1,140 from 2012 to 2027.
26. CS Policy CS12 states that all development proposals must conserve and enhance the borough's natural environment, including biodiversity, habitats, protected trees, and landscape character, in order to maintain and improve environmental quality, and contribute to the objectives of the adopted Greenways Strategy and the Hertsmere Green Infrastructure Plan. Policy SADM11 covers landscape character and asserts that development will be managed to help conserve, enhance and/or restore the character of the wider landscape across the borough. Reference is made to the Hertfordshire Landscape Character Assessments.

27. In respect of Green Belt, CS Policy CS13 refers to a general presumption against inappropriate development within the Green Belt, as defined on the Policies Map and confirms that such development will not be permitted unless very special circumstances exist. Development proposals, including those involving previously developed land and buildings, in the Green Belt will be assessed in relation to the Framework. Further villages and Green Belt sites are named, but are not of direct relevance here. Policy SADM22 confirms that the Green Belt boundary is shown on the Policies Map, while Policy SADM26 outlines criteria for development standards in the Green Belt, including development's scale, height and bulk being sympathetic to and compatible with its landscape setting and not being harmful to the openness of the Green Belt.
28. CS Policy CS16 looks to minimise and mitigate development's environmental impact, with reference to avoiding development in the floodplain and close to river corridors unless the requirements of the ST and ET have been met and flood prevention/mitigation measures are in place as required by the Environment Agency; incorporating the use of sustainable urban drainage where appropriate to reduce risk of flooding; and achieving reduced energy consumption and using energy from renewable resources. CS Policy CS17 deals with energy and CO₂ reductions.
29. Amongst other things, CS Policy CS18 states that provision of required key community facilities should be made as part of the development in consultation with the local community and local service providers and in order to meet or fund any infrastructure impact, having regard to the provisions of CS Policy CS21, while CS Policy CS19 supports proposals for the provision or dual use of key community facilities, including educational, healthcare and recreational facilities, subject to any environmental constraints and other relevant policies. CS Policy CS21 deals with planning obligations.
30. Policy SADM13 confirms that the natural environment of watercourses and areas of water will be improved wherever possible through Policy SADM16, which sets out key principles for watercourses. Policy SADM13 advocates that watercourses, including culverts, land adjacent to rivers, functional floodplains and flood storage areas should be restored to their natural state. It also states that new built development will normally be directed to Flood Zone 1, in preference to Flood Zones 2 or 3 as shown on the Policies Map. Policy SADM14 is set out in more detail in paragraphs below on flood risk. Policy SADM15 sets out criteria for sustainable drainage, particularly for major developments.
31. With regard to highways and access, Policy SADM40 sets out requirements for development to be accessible by a range of transport modes, including sustainable transport, to have safe and convenient routes through the site and access to adjoining routes, and not to cause or add significantly to road congestion or unduly harm the flow of vehicles, amongst other things.
32. The Draft Hertsmere Local Plan (Regulation 18, dated September 2021) (DHLP) included Policy H10 which sought to allocate sites for housing. Site allocation B1: Land East of Little Bushey Lane, Bushey included the site, Hart's Farm Stables, and land north-east of the stables for housing development (up to 350 homes) with community facilities, local retail, and flexible workspace, land for a two-form entry primary school, and public open space. Although the DHLP underwent public consultation, the Council decided on 27 April 2022 to set

aside the DHLP. It is agreed that no weight should be afforded to the DHLP, though the evidence base for the DHLP is a material consideration.

Purposes and openness of the Green Belt

33. The Metropolitan Green Belt is a strategic mechanism which stretches across a number of counties, including Hertfordshire. It is agreed between the main parties that the site is not one which makes an important strategic contribution to the Green Belt.
34. In developing the DHLP's evidence base, the Council commissioned the Green Belt Assessment (Stage 1) Report: Methodology and Assessment of Green Belt Parcels (January 2017)(Stage 1 assessment). The Stage 1 assessment involved considering how different areas perform against the Green Belt purposes set out in the Framework. Subsequently, further assessment on smaller parcels was undertaken as part of the Hertsmere Green Belt Assessment Stage 2: Final Report (March 2019)(Stage 2 assessment) and the Annex Report (January 2019)(Stage 2 assessment annex).
35. The Stage 1 assessment's Green Belt Parcel 6 is a large parcel located to the north and east of Bushey Heath/Bushey and includes the site. It describes the parcel as being connected to the large built-up area of Watford and forming part of the essential gap between Watford and Bushey Heath/Bushey Village and part of the essential gaps between these settlements and North Bushey and Elstree. It was found to be predominantly rural in character with more urbanising influences in the west and east. The Stage 1 assessment recommended that parcel 6 performs strongly against the purposes, but there is clear scope for sub-division. It stated that the area south of Little Bushey Lane, which may score less strongly, should be considered further.
36. Forming part of parcel 6, parcel SA-57 within the Stage 2 assessment and annex comprises some 57 hectares of land between Little Bushey Lane and the road corridor and includes the site. The Stage 2 assessment annex concludes that removal of parcel SA-57 from the Green Belt would have a limited impact on the strategic Green Belt's role as it is already characterised by urban influences and contained by the settlement edge and the road corridor, which would prevent any further sprawl and act as an additional barrier to the merging of settlements. It states that limited views to wider countryside and moderate levels of containment by urban form mean that this area is not a visually sensitive part of the Green Belt. It found that parcel SA-57 could be considered for release, particularly the southern area.
37. Notwithstanding that the DHLP was set aside prior to examination and albeit that larger parcels than the site itself were assessed at both stages, the Stage 1 and 2 assessments provide helpful assessment. While I note Mr Radmall's view that the Stage 1 and 2 Green Belt assessments are different in their strategic scope from his locally focused evidence, I afford the assessments significant weight as material considerations.

Openness of the Green Belt

38. The Framework confirms at paragraph 137 that the fundamental aim of Green Belt policy is to prevent urban sprawl by keeping land permanently open; the essential characteristics of Green Belts are their openness and their permanence. Openness can have both spatial and visual elements as

highlighted by the PPG¹ which considers that, when assessing the impact of a proposal on the openness of the Green Belt, a number of matters may need to be considered. These include openness being capable of having both spatial and visual aspects; the duration of the development, and its remediability; and the degree of activity likely to be generated, such as traffic generation.

39. The site is presently used for horse grazing and by pedestrians using PROW 33 and 40. The proposed development would introduce a significant volume of vehicular and pedestrian movements associated with housing, the school and mobility hub. This would dramatically alter the existing degree of activity on site. Furthermore, the change in the nature of the site would be long-standing. Both of these factors would have a negative effect on openness.
40. Apart from the presence of pylons, the site itself is free from built development, with limited post and rail fencing, hedgerows and trees providing enclosure and separation of fields. While this is not unique, the proposed development would introduce a significant quantum of built development. Spatially, built form or supporting infrastructure would indicatively occupy some 57% of the site or 10.4 hectares, with the remainder to be indicatively laid out as green infrastructure. While the proposed development would represent a considerably smaller site than parcel SA-57 in the Stage 2 assessment and matters of appearance, landscaping, layout and scale are reserved for determination with scope for mitigation of the spatial effect, the proposed development would significantly reduce spatial openness.
41. In terms of visual openness, views of the site from Little Bushey Lane are presently relatively open, due in part to the declining quality and extent of hedgerows. Despite some sections of hedging and trees and the pylons, it is possible to look across the site from Little Bushey Lane and see an area of open fields, with housing, Caldecote Farm, the Niland Conference Centre, Rosary Priory Convent and Immanuel College to the south and south-east and Hart's Farm and housing at Rossway Drive to the west and north-west. Given the likely concentration of development close to existing built development at Little Bushey Lane and the increased level of vehicular activity, even with sympathetic landscaping, the localised effect on visual openness would be significant and long-standing.
42. Looking from viewpoints outside the site along the road corridor, the site is viewed with the aforementioned built development on the edge of Bushey. Given the strong presence of built form adjacent to the site, this gives a sense of the semi-urban nature referred to in relation to parcel SA-57 in the Stage 2 assessment annex and reduces the site's rurality given its overall containment by urbanising influences. Though there would be a significant reduction in visual openness as built development would be in greater proximity to the road corridor, this would be partly mitigated by the green corridor acting as a buffer.
43. When standing within the site, one presently experiences the greatest sense of openness when walking along PROW 40. Although this route would be retained, its future users would experience significantly altered surroundings as built form would adjoin and enclose the earlier part of the route from Little Bushey Lane up to the proposed green corridor. Even with soft landscaping and open

¹ Paragraph 64-001-20190722: What factors can be taken into account when considering the potential impact of development on the openness of the Green Belt?

spaces at intervals along the proposed route with lateral views along street corridors, this would represent a significant change in visual openness.

44. Considering the totality of effects, the proposed development would cause significant harm to openness that would be both visual and spatial, long-standing, and would result in a considerably greater level of activity.

Purposes of the Green Belt

45. As defined by paragraph 138 of the Framework, the Green Belt serves five purposes. Though both assessments refer to the purposes numerically rather than alphabetically, I have used the nomenclature within the Framework. The main parties agree that purposes d) and e) are not of relevance. I have no reason to disagree.
46. The application of purpose a) on checking the unrestricted sprawl of large built-up areas hinges on the definition of a large built-up area. The Stage 1 assessment has Borehamwood as the only tier 1 settlement with Bushey and Potters Bar at tier 2, while the Stage 2 assessment defines Borehamwood as the only large built-up area within Hertsmere, with other towns such as Watford and parts of Greater London being large built-up areas.
47. Although the Stage 1 assessment found that parcel 6 met purpose a) moderately, this is unsurprising given the parcel's large size and position partially abutting Watford's built-up area. At Stage 2, the smaller parcel of SA-57 was found not to meet purpose a) as it did not abut the edge of a distinct large built-up area in either physical or perceptual terms. Mr Radmall's evidence conflicts with the Council's earlier Green Belt assessment work as he sees Bushey as a large built-up area on the map and when driving through it.
48. While Bushey's village core has been retained, post-war suburban development has altered the overall perception of Bushey as a place. Bushey is larger than some nearby settlements, such as Elstree. Notwithstanding this, Bushey remains a smaller built-up area than Borehamwood and spatial separation from other large built-up areas is retained. Bushey does not therefore form the large built-up area outlined in purpose a). If I had found that Bushey was a large built-up area, sprawl or the perception of sprawl would be restricted by the existing housing development to the north-west, the south, and south-west, as well as by the road corridor and the green corridor along the Bushey Heath Drain. As such, I find that there would be no harm to purpose a).
49. Turning to purpose b), which deals with preventing neighbouring towns from merging into one another, the Stage 1 assessment found parcel 6 to meet purpose b) strongly and the Stage 2 assessment found parcel SA-57 to score moderately against purpose b). Although the proposed development would reduce the gap between built development in Bushey and neighbouring settlements, it would not be closer to Radlett than the closest point of the Rossway Drive development. Although it would slightly reduce the gap between Bushey and Borehamwood, given the physical severance of the two settlements by the road corridor and the intervening land beyond the road corridor, I consider that the reduction in the gap would be extremely limited.
50. Even if Elstree were to be considered a town rather than a village, the proposed development would not extend towards Elstree as much as parcel SA-57 and would continue to maintain a significant gap between the settlements.

This gap is further defined by the road corridor and by the steeper landform to the south-east. These would assist in reducing any perceptual coalescence. Additionally, the green corridor within the proposed development would reduce any perception of merging of Bushey and Elstree. I find therefore that there would be very limited harm in respect of purpose b).

51. In respect of purpose c) on assisting in safeguarding the countryside from encroachment, the Stage 1 assessment found parcel 6 to meet purpose c) moderately, and the Stage 2 assessment found parcel SA-57 to meet the purpose weakly. Mr Clark considers the harm to purpose c) would be limited, while Mr Radmall finds that the site makes a moderate contribution to purpose c) and considers that semi-urban character applies to the site's setting, not to its intrinsic character. The lies next to, but outside the settlement boundary.
52. The site is undoubtedly affected by urbanising features, including the road corridor and housing at Rossway Drive and on and adjoining Little Bushey Lane. The sense of urbanisation is somewhat reduced to the south-east as the site adjoins further fields and paddocks, with Caldecote Farm, the Niland Conference Centre, Rosary Priory Convent and Immanuel College further away from the site abutting Elstree Road. While there is intervisibility between the site and the wider countryside beyond the road corridor, the site does not have a wholly rural character given its aforementioned setting. Even when walking across the fields which form the site, its rural attributes and sense of tranquillity are compromised by the visual appearance of adjoining built form and the aural experience of vehicles on the neighbouring road corridor. Therefore, I consider that the harm in respect of purpose c) would be modest.

Character and appearance

53. The proposed development is in outline form, with parameter plans and an indicative masterplan. The landscaping would be part of reserved matters and the appellant is not restricted specifically to the aforementioned plans. However, the aforementioned plans demonstrate what could be brought forward on site and include a landscaped buffer between proposed built development and the road corridor. It is a reasonable assumption that landscaping would be located generally as shown on these plans.
54. Primary mitigation would indicatively take the form of setting the built development back from existing watercourses on higher ground. In addition to the use of the existing watercourses to create the proposed development's structure, further consideration has been given to the existing hedgerows and trees to visually, physically and perceptually connect the built-up area with its wider setting. Secondary mitigation takes the form of illustrative landscaping proposals, with green spaces, linkages, hedgerows, trees, and watercourses.
55. The site lies within the National Character Area 111: Northern Thames Basin, an area extending from Hertfordshire to the Essex coast. Though both main parties agree that the site is not devoid of landscape value, it is also agreed by the main parties that the site and its vicinity do not constitute a valued landscape in the terms of paragraph 174 a) of the Framework which seeks to protect and enhance valued landscapes in a manner commensurate with their statutory status or identified quality in the development plan.
56. As far as the Hertfordshire County Landscape Character Assessment (HCLCA) is concerned, the site's north-western third falls within Landscape Character Area

(LCA) 22: Borehamwood Plateau, while the south-eastern two-thirds fall within LCA23: Elstree Ridge and Slopes. The character assessments for LCA22 and LCA23 highlight both positive and negative features.

57. LCA22 is described in the HCLCA as an area of gently undulating landform and considerable pasture within an intact landscape framework, with tall hedgerows and field trees containing views into and across the landscape. Positive reference is made to the two reservoirs and to parkland areas within the grounds of private schools, but this is not relevant to the site. It is asserted that LCA22's integrity is diluted on approaching towns that enclose to the east, west and south. Within LCA22's key characteristics, negative reference is made to fragmentation and disruption by the road corridor, pylons and raw edges of built development. In terms of visual and sensory perception, LCA22 is generally coherent apart from to the south-west where there is a mix of recreational, industrial and agricultural uses and the noisy road corridor contributes to the downgrading. The HCLCA identifies that the aim should be to improve and restore LCA22.
58. LCA23 is located between Bushey Heath and Borehamwood. The HCLCA illustrates its landscape character as being an area never very far from the impact or presence of built development despite its general containment behind and among vegetation. The area's spine is formed by a marked and well-treed ridge, while pasture, with some overgrazing and poor fencing, dominates the side slopes. Though largely screened by planting, the M1 passes through the area and is described as noisy. Amongst the key characteristics described in LCA23's summary profile, reference is made to considerable equestrian pasture, increasing impact of horse grazing, and the road corridor creating a major impact. When looking at physical influences and land cover and land use, the HCLCA refers to the primary land use being pasture, and exclusively for horses, with some paddocks seeming to be suffering from over-grazing. The HCLCA identifies that the aim should be to conserve and restore LCA23.
59. The site consists of overgrazed fields with hedgerows and trees in varying condition. There has been some loss of hedgerow and introduction of fencing. While open pasture grassland is representative of LCA23 in particular and is a positive feature, the ongoing degradation of the fields is unfortunate, but does not diminish their inherent value. Despite the degradation and their relative lack of rarity, the fields have a strong sense of place. Although the site is not within a valued landscape, the Landscape Institute's Technical Guidance Note 02/21: Assessing landscape value outside national designations (2021) advises that deliberately neglecting an area of landscape and allowing its condition to deteriorate should not be allowed to diminish its value in a planning context.
60. Though screened largely from view, the road corridor is intrusive within the locality, given vehicle noise depending on the wind direction. The road corridor physically separates the site from adjacent countryside. Additionally, the aerodrome exerts some aural and visual influence, with planes taking off and landing. Furthermore, Bushey's settlement edge is very visible from the site. Indeed, the settlement edge exerts a substantial influence on the site's setting.
61. The proposed development would develop open fields, thereby reducing the overall extent of open pasture fields within the relevant LCA. Even though only part of the site would contain built development and some parts of the site would remain open, the existing field pattern would not remain. While there are

urbanising effects with relatively stark edges of existing built form, I consider that the open fields themselves are sensitive and highly susceptible to change. There would be a major adverse effect on the open pasture fields at Year 1, which would continue in Year 15 as planting would not alter the overall effect of the loss of the open pasture fields.

62. Turning to landform, the parties' views differ quite substantially in terms of the effects at Years 1 and 15. As part of developing the DHLP, the Council commissioned LUC to produce Outline Landscape Appraisals for potential development sites in Hertsmere: Final report (October 2020). The LUC report outlines constraints for potential allocations, including Site 4: HEL215, HEL336 and B1 (HEL201): Land east of Little Bushey Lane of which the site is part.
63. The LUC report refers to LCA22 and LCA23 and confirms that effects on these LCA could be avoided or minimised by retaining public access with opportunities for countryside experience and providing opportunities to experience longer views from elevated areas; retaining all existing vegetation as far as possible, particularly mature trees; and enhancing the on-site watercourse, floodplain character and valley landform. The appellant has sought to address these points. However, land levels would change in some areas and the gently undulating landform would alter significantly with the introduction of built form and supporting infrastructure and would no longer be clearly visible. As such, the degree of physical change would be marked and would be of a moderate-major adverse level at Years 1 and 15.
64. There would be greater visual effects at Years 1 and 15 on views 2 (south from PROW 33), 3 (View east from Little Bushey Lane), 4 (View north-east from little Bushey Lane), 20 (View south-west from PROW 40) and 21 (View west from PROW 40 bridge over M1) than for the remainder of the landscape viewpoints. In view 3 in particular, the proposed access road would dominate the foreground, while views from PROW 33 and 40 would be significantly affected by enclosing built development, despite green and blue infrastructure proposals. The sense of walking through the countryside, albeit close to the urban edge, would be fundamentally eroded.
65. While the appellant views the overall effect on landscape character to be limited by reason of the existing landscape's condition, existing built form's urbanising effect, the area's fragmentation and disruption by the road corridor, and the aforementioned primary and secondary mitigation, I consider that all these factors would not overcome the significant change that would occur within the site. The site's open character would be lost due to the introduction of an extensive area of built form and retained landscape features would be subsumed within the built-up area, thereby reducing their visual influence.
66. I conclude that the proposed development would have a significant harmful effect on the character and appearance of the area, contrary to CS Policies SP1 and CS12 and SADM Policy SADM11, as set out above. It would also conflict with paragraph 174 b) of the Framework insofar as it seeks to recognise the intrinsic character and beauty of the countryside. This has significant weight.

Flood risk

67. Within the north-eastern part of the site, the Bushey Heath Drain, an Environment Agency Main River, runs south-east to north-west. Some ordinary watercourses run through the site, one travelling along a central field

boundary, while another runs through the southern part of the site. The Hilfield Park Reservoir is approximately 350m to the north-east, while Aldenham Reservoir is some 1.5km to the east.

68. The Environment Agency publishes mapping for different sources of flooding. This data indicates that much of the site is in Flood Zone 1 for flooding from fluvial sources. However, the course of the Bushey Heath Drain watercourse falls within Flood Zones 2 and 3. Approximately 10% of the site is also affected by reservoir flood risk from Hilfield Park Reservoir.
69. The Environment Agency's data indicates that there is a surface water flow path flowing through the east of the site in a south-east to north-west direction, consistent with the Bushey Heath Drain and adjacent land. An area of medium and high surface water risk lies along the field boundary across the centre of the site. Additional potential surface water flow paths at low and limited areas of medium flood risk are indicated in the site's south-west and north-west areas. This mapping does not account for the impact of climate change. Surface water flooding on the site could occur as a result of overland surface water flow paths and from the site's own surface water run-off.
70. Paragraph 159 of the Framework confirms that inappropriate development in areas at risk of flooding should be avoided by directing development away from areas at highest risk (whether existing or future). Where development is necessary in such areas, the development should be made safe for its lifetime without increasing flood risk elsewhere.
71. Paragraph 162 of the Framework states that the aim of the ST is to steer new development to areas with the lowest risk of flooding from any source. It also asserts that development should not be allocated or permitted if there are reasonably available sites appropriate for the proposed development in areas with a lower risk of flooding, and confirms that the strategic flood risk assessment will provide the basis for applying this test. The sequential approach should be used in areas known to be at risk now or in the future from any form of flooding. The PPG² confirms that even where an FRA shows the development can be made safe throughout its lifetime without increasing risk elsewhere, the ST still needs to be satisfied.
72. Policy SADM14 deals with flood risk and contains numerous criteria, many of which pertain to principles for managing and mitigating flood risk on site. However, the first two criteria (i) and (ii) relate to avoiding and reducing the risk of flooding by (i) locating development within areas of lower flood risk through the application of the ST and then applying an ET in line with the Framework; and (ii) ensuring that development proposals in flood risk areas actively manage and reduce flood risk by applying the sequential approach at site level. The supporting text to Policy SADM14 does not provide further detail on how the ST should be applied.
73. No mention is made of Policy SADM14's criteria (i) and (ii) in the appellant's FRA. Paragraph 6.2 of the appellant's FRA states that ST is generally required for sites that have not been allocated within the Local Plan. It confirms that application of the ST falls outside the scope of the FRA.

² Paragraph 7-023-20220825 What is the aim of the sequential approach?

74. The appellant did not undertake an ST prior to submitting the application, or at any time during the application's lifetime. This is somewhat surprising as the Framework confirms that the sequential approach should be used in areas known to be at risk now or in the future from any form of flooding. The onus was on the appellant to undertake the ST. The Framework has not altered since July 2021, though the PPG was updated more recently in August 2022 with particular reference to the need to consider all sources of flooding including surface water flooding. Despite repeated opportunities to do so in both consultation responses and through the officer report, neither the Council nor the LLFA confirmed that the ST was required until after the appeal was lodged.
75. Instead, the appellant sought to locate built form within Flood Zone 1, the area at the lowest risk of fluvial flooding. However, when considering the ST, the Framework refers to development and not housing. Furthermore, consideration needs to be given to all sources of flood risk affecting the site. Accordingly, I consider that it is necessary to consider the entire site when establishing whether the ST should be applied.
76. The ST has now been undertaken and the Council has provided its views on the appellant's findings. The main areas of disagreement relate to the ST area of search, the parameters for site size and grouping of sites, what constitutes 'reasonably available', and whether any sites fall within that category other than the site itself. I cover these matters below.
77. The LLFA has undertaken more nuanced work than the appellant on whether sites would be at a lower risk of flooding and has also considered the variation of risk. I agree that the granularity of the appellant's approach to assessing the level and variation of flood risk is limited, and have had regard to Ms Waters' more detailed data on flood risk in reaching my decision.

Area of search

78. The Framework does not define the ST search area's extent. The PPG³ advises that it will be defined by local circumstances relating to the catchment area for the type of development. This is not exhaustive. The PPG asserts that this may be clear for some developments, for example a school catchment area, but also notes that it could be wider than a local planning authority boundary for nationally or regionally important infrastructure. The PPG⁴ confirms that the local planning authority will need to determine an appropriate search area, based on the development type proposed and relevant spatial policies.
79. The Council's Strategic Flood Risk Assessment (Level 1)(May 2018) at paragraph 4.3 states that the ST area of search could be the borough area, or a specific catchment if this is appropriate and justification is provided, such as a school catchment area or the need for affordable housing within a specific area identified for regeneration in Local Plan policies.
80. Without any engagement with the Council or LLFA, the appellant defined the ST area of search as the whole borough. This is not consistent with the aforementioned PPG. It was posited at the Inquiry that this was due to the tight Inquiry timescales, but this should not have been seen as a limit to the production of appropriate evidence or to reaching agreement on area of search parameters. Indeed, I offered to hold the remainder of the Inquiry in October

³ Paragraph 7-027-20220825 How should the Sequential Test be applied to planning applications?

⁴ Paragraph 7-029-20220825 Who is responsible for deciding whether an application passes the Sequential Test?

2023, which could have allowed more time for discussion. Neither main party sought to extend the timescales for the ST or for the response to the ST.

81. The Council has not produced guidance on the appropriate area of search for common development types or an up-to-date register of 'reasonably available' sites, clearly ranked in flood risk preference⁵. However, the Council considers that it would have been appropriate to consider parts of Hertsmere and the other Council areas within the South West Hertfordshire Housing Market Area (HMA), namely Dacorum, St Albans, Three Rivers, and Watford within a 10 mile zone from the site. However, the zone is not evenly drawn, excluding neighbouring London boroughs. Furthermore, little clarity was offered by the Council as to why the whole HMA was not chosen.
82. The 10 mile zone appears to be based on a 15 mile zone within an appeal⁶ for a caravan and holiday lodge scheme in Newark and Sherwood, an approach which that Inspector considered overly restrictive. As the 15 mile zone relates specifically to the level of access for such schemes to fishing lakes and other associated recreational facilities, the two appeals are distinctly different from one another. Indeed, none of the elements of this appeal for housing, a primary school and a mobility hub are particularly unusual or 'niche'.
83. The Council's Appendix C identifies circa 70 sites outside Hertsmere, with only site numbers and indicative unit numbers provided. It is unclear what flood risk levels are relative to the site or if these sites would be reasonably available. I give these sites very limited weight in reaching my conclusions.
84. There is an absence of evidence that the proposed development would constitute nationally or regionally important infrastructure. While the borough is not particularly large and the site is close to the borough boundary, any residential scheme such as the appeal scheme would contribute to meeting housing need wherever it was located within the borough. Community facilities such as the school and mobility hub would not be out of place on other sites within the borough. Without convincing evidence to the contrary and despite the appellant's failure to engage with the Council on setting the area of search, I find that the appellant has taken a reasonable and pragmatic approach to defining the area of search as the borough in this instance.

Reasonably available sites

85. The PPG⁷ describes reasonably available sites as being those in a suitable location for the type of development with a reasonable prospect of being available to be developed at the point in time envisaged for the development. It asserts that such sites could include a series of smaller sites and/or part of a larger site if capable of accommodating the proposed development. It confirms that such lower-risk sites do not need to be owned by the applicant. I can see no evidence in the PPG that it is for the Council to provide evidence on whether a site is reasonably available. Indeed, as the Council does not undertake the ST, it appears to be a task for the appellant.
86. Having referred to an appeal⁸ in Framlingham, Suffolk which looked at sites some 15% - 20% larger or smaller than the Framlingham site, the appellant

⁵ Ibid.

⁶ Appeal APP/B3030/W/22/3309438, decision issued 14 April 2023.

⁷ Paragraph 7-028-20220825 What is a "reasonably available" site?

⁸ Appeal APP/X3540/W/20/3250557, decision issued 29 September 2020.

has considered sites 25% above and below the size and capacity of their site, that is sites between 13.6 and 23.1 hectares and capable of accommodating between 232 and 388 homes. No clear maximum size parameter has been set by the Council, though a lower threshold of 80 homes was applied, without particularly clear evidence as to how that was reached. In addition, the appellant has considered larger sites of which the proposed development could form a part and smaller sites where they could be grouped, though the focus was on smaller sites being next to or close to one another.

87. Despite being referred to by the Inspector in the Framlingham appeal as a standard approach, I can see no reference to a standard approach in either the current PPG (August 2022) or in the previous PPG (March 2014). The Framlingham appeal predates the current PPG and was for four houses. It is not materially comparable in size to the appeal before me, and in the absence of detailed evidence from that appeal, the origins and veracity of this standard approach remain unclear to me. In any event, no such percentages are set out in the current PPG and I can see no reason to refer to a 15% - 20% margin and then introduce a more 'conservative' 25% allowance above and below the site's size and capacity. As such, I am not convinced that the appellant's maximum and minimum site sizes and site capacities were robustly chosen and were consistent with the PPG's advice on assessment of a series of smaller sites or larger sites of which the development could form part.
88. With regard to the grouping of smaller sites, the proposed development would comprise around 310 homes, land for a primary school and a mobility hub, as well as green infrastructure. Although this represents a large, possibly even strategic scheme with non-residential elements, I see no reason why a number of smaller sites could not accommodate all these elements. As in the North Somerset appeal⁹, smaller sites would not necessarily need to be contiguous. I agree with the Council that a series of sites would potentially indicate three or more sites. Equally, I am not convinced that part of a larger site would not represent a reasonable proposition in some circumstances, though considerably larger sites may take longer to bring forward and would not be reasonably available.
89. The appellant estimates that the proposed development would start on site in late 2024 with first completions in 2025. The Council considers that 2027 would see the first completions as it assumes two years for planning permission and two further years for discharge of conditions. I have had regard to the discussion of timescales set out in the Lichfields' Start to Finish document (2020), Table 2 of the Flood Risk Sequential Test SOCG and the Hertsmere Housing and Economic Land Availability Assessment (HELAA) methodology in Appendix B to Ms O'Brien's ST Rebuttal.
90. Given the need to undertake hydraulic modelling, determine reserved matters and discharge detailed and relatively onerous pre-commencement conditions on matters such as design coding, access works and drainage, I consider it likely that the start on site and first completions would slip somewhat in the real world, though not to as great an extent as the Council envisages. I acknowledge that the appellant, a national housebuilder, is not at a standing start. The appellant has freehold ownership of the land, has already made considerable progress towards scheme delivery in terms of the first two years

⁹ Appeal APP/D0121/W/22/3313624, decision issued 20 June 2023.

of the Lichfields and HELAA methodology, and has undertaken archaeological trial trenching. However, I consider that the suggested start date is overly optimistic and is more likely to result in completions starting in 2026.

91. Even if I agreed with the appellant's first completions in 2025, I concur with the Inspector in the North Somerset appeal that being available to be developed does not necessarily mean that the development of an alternative site would need to follow the trajectory of start and build out dates set out for the appeal scheme. It is only necessary for the alternative land to be available to be developed.
92. For this appeal, the ST approach should therefore assess alternative sites falling within Hertsmere's administrative boundary; sites of different sizes, including smaller sites where development could be delivered across one or more sites and parts of larger sites; and sites which would be available for development at the point in time envisaged for the proposed development.
93. Using Council documents¹⁰ to source sites, the appellant assessed 244 sites and undertook more detailed assessment of 31 sites. Unfortunately, the appellant did not have access to the 2022 call for sites or the 2022 HELAA. Their ST reached the conclusion that their site would be the only sequentially preferable site. The Council considers that other sites would have lower flood risk and would potentially be reasonably available, rendering them sequentially preferable. I cover the 14 disputed sites in the Flood Risk Sequential Test SOCG below.
94. HEL181 Compass Park, HEL347 Land to northeast of Cowley Hill, HEL362 South of Potters Bar, and HEL379 Kemprow Farm, Radlett are larger sites with lower flood risk than the site. The appellant's evidence with regard to the reasonable availability of these larger sites is not compelling as it lacks detail on how long it might take for these sites to come forward and whether this would be outside the expected timeframe for delivering the proposed development. Despite having been reliant on timescales from the 2019 HELAA, the appellant has not contacted landowners to understand availability and likely timing of delivery. While I understand the appellant's concerns about time taken for land acquisition, there is simply not sufficient information to demonstrate to me that these sites would not be reasonably available on the basis of timescales.
95. HEL176 Former Bushey Golf and Country Club, HEL177 Dove Lane, HEL209a Land North of Barnet Lane, HEL212 Land North of Watford Road, HEL231 Starveacres, HEL274 Land at Edgwarebury House Farm, HEL349X Shenley Grange, HEL358 Land south of Shenley Road, and HEL521 Bushey Hall Farm are all at lower risk of flooding than the site. The appellant has ruled them out on the basis of the appellant's lowest site size or dwelling numbers, which I have found not to be supported by the PPG or other compelling evidence.
96. HEL349X Shenley Grange and HEL358 Land south of Shenley Road have recently had planning applications refused and the LLFA objected to both on flooding issues. However, this does not mean that either site would not be at comparatively lower flood risk than the site. While an appeal has been lodged for HEL358 Land south of Shenley Road, this would not automatically remove the site from consideration. As far as HEL176 Former Bushey Golf and Country

¹⁰ Housing Land Supply Trajectory (base date 1 April 2022); Brownfield Register (2022); Housing and Economic Land Availability Assessment (2019); DHLPP; SADM, and Elstree Way Corridor Area Action Plan (2015).

Club is concerned, the emerging planning application should not be seen as a negative. For HEL209a Land North of Barnet Lane, HEL349X Shenley Grange, and HEL358 Land south of Shenley Road, other housebuilders holding options is not sufficient in the absence of detail to prevent the sites from being reasonably available.

97. For all of the aforementioned smaller sites, I recognise that there are a range of different constraints affecting them, but no site is likely to be without constraints. I consider that it has not been adequately demonstrated that they are not reasonably available and that the proposed development could not be delivered through a series of smaller sites.
98. Site HEL355 Heathbourne Green was to be allocated for 800 homes. Although it appears to be at lower risk of flooding than the site, its development timescale is a 16 year plus horizon. This site is not reasonably available.
99. In summary and having considered all the disputed sites, I find that some 13 sites would potentially fall within the meaning of reasonably available. It has therefore not been demonstrated that the proposed development could not be located elsewhere in an area at lower risk of flooding. Though I note that the appellant considers that the ET is passed, I have not applied the ET as I have found that the appeal would fail the ST.
100. I conclude the proposed development would not be in a suitable location with regard to local and national policies relating to flood risk. Accordingly, it would conflict with paragraph 162 of the Framework, CS Policies SP1 and CS16, and SADM Policy SADM14, as set out above. This has very substantial weight.

Other matters

101. I have been referred to numerous legal judgments and appeal decisions. Both main parties have sought to draw comparisons and similarities between the appeal decisions before me for a variety of reasons. Appeal decisions are unlikely to be directly comparable to one another, with differences in the size and type of development, planning policy, and housing land supply positions to name but a few differing factors. In this decision, I have referred to specific legal judgments and appeal decisions where directly relevant.
102. Many representations were made in respect of the planning application and the appeal. In addition to raising matters covered above, there were concerns about the effect of the proposed development on biodiversity, equestrianism, living conditions of neighbouring occupiers, archaeology, local infrastructure, and highway safety, including the effect on the wider strategic road network. Concern was also raised about pollution and disruption during construction. I have not dealt with these matters in any further detail given my decision.

Other considerations

103. I turn now to the other considerations advanced by the appellant, that they consider would collectively amount to very special circumstances.
104. The Framework's policy imperative to increase the supply of housing and radical change in approach from its predecessor policy documents is discussed

in the Gallagher Homes legal judgment¹¹. Paragraph 60 of the current Framework seeks to support the Government's objective of significantly boosting the supply of homes. It clarifies that it is important that a sufficient amount and variety of land can come forward where it is needed, that the needs of groups with specific housing requirements are addressed and that land with permission is developed without unnecessary delay. The appeal scheme is described as being for up to 310 homes, though the appellant has confirmed that it may provide slightly closer to 300 if accounting for alterations to the parameter plans for drainage purposes.

105. CS Policy CS1 confirms that the Council will make provision for at least 3,990 additional dwellings between 2012 and 2027, an annual minimum of 266 dwellings. However, the CS is over five years old and the Inspector who examined the CS sought early review given her concerns about the housing requirement¹². Due by January 2016, that early review did not take place.
106. Some 80% of Hertsmere and almost all land outside settlement boundaries is within the Green Belt. It is agreed between the main parties that the Green Belt boundaries and the settlement boundaries are substantively out of date. Reviewing and altering Green Belt boundaries substantially for the first time since the First Review of the Hertfordshire County Development Plan in 1971, the DHLP and its evidence base was predicated on releasing Green Belt land to meet future housing needs. Indeed, both main parties agree that use of Green Belt land for housing is inevitable to meet housing needs, in addition to use of brownfield land and densification. However, the DHLP was set aside in 2022.
107. The most recent Local Development Scheme (April 2021)(LDS) relates only to the DHLP. Given the absence of an up-to-date LDS and a clear pathway for Local Plan production, Hertsmere finds itself in a Catch-22 situation with planning taking place by planning application and appeal. I have little confidence at this point that the Council is moving forward effectively with efforts to meet local housing needs through the plan-led system. Regrettably, a new Local Plan is years away. In the meantime, it is agreed between the main parties that Bushey is a tier 2 settlement within the adopted settlement hierarchy and that it forms a sustainable location for development, whether one considers the current development plan, the DHLP's evidence base, or the DHLP itself in which the site was proposed for allocation.
108. The Council cannot demonstrate a five-year supply of deliverable housing and the standard method should be used to calculate the housing requirement in accordance with paragraph 74 of the Framework. However, the parties disagree on the extent of the shortfall, with the Housing Land Supply SOCG (2 May 2023) indicating the appellant's position of 1.23 years' housing supply or 942 dwellings from 2022/23 to 2026/27 and the Council's position of 2.25 years' housing supply or 1,713 dwellings over the same time period.
109. As a result, the shortfall is between 2,104 and 2,875 homes for the Council and the appellant respectively. My attention has been drawn to a legal judgment¹³ in respect of the extent of the shortfall. Both the appellant's and Council's supply figures are woeful, representing extremely substantial shortfalls symptomatic of a chronic failure to deliver housing. Sadly, and as

¹¹ Gallagher Homes Ltd v Solihull MBC [2014] EWCA Civ 1610.

¹² Report on the examination into Hertsmere Revised Core Strategy, issued 5 December 2012.

¹³ Hallam Land Management Ltd v SSCLG and Eastleigh Borough Council [2018] EWCA Civ 1808

highlighted by the Inspector in the Harris Lane, Shenley appeal¹⁴, this is likely to worsen further given the absence of progress on plan-making. Even on the Council's figures, the Council is presently amongst the worst performing in the country on housing land supply and without proper plan-making, efforts to resolve housing land supply issues are likely to be limited in extent.

110. The proposed development would deliver up to 310 residential units. In doing so it would support the Government's aim to significantly boost the supply of housing. While housing has been provided in Bushey in recent years, this has done little to improve the borough-wide shortfall of housing whichever position taken. If I were to endorse the appellant's worst-case scenario on the Council's five-year housing land supply, in light of the scale of development proposed and of the aforementioned local and national circumstances, I would give the provision of market housing very substantial weight.
111. For affordable housing, the picture is no less bleak. The South West Hertfordshire Strategic Housing Market Assessment 2016 (SHMA) identifies an annual need for 434 net affordable dwellings between 2013 and 2036, while the South West Hertfordshire Local Housing Need Assessment 2020 (LHNA) refers to an annual need for 503 affordable dwellings between 2020 and 2036. Data from the Department for Levelling Up, Housing and Communities shows that at 31 March 2022, 799 households were on the Housing Register. It is agreed in the Affordable Housing SOCG (3 May 2023) that from 2013/14 onwards, net affordable housing completions have averaged 54 per year compared to the SHMA need for 434 net affordable dwellings. This results in an average annual shortfall of 380 affordable homes. Affordable housing forms just 14% of housing completions, against CS Policy CS4's target of 35%.
112. Even bearing in mind any affordability issues addressed by the standard method and the policy-off nature of the SHMA and LHNA figures, there is a pressing, persistent and acute need for affordable housing within Hertsmere, which should be addressed as a matter of urgency. This is an area where house prices are well in excess of the national or even the East of England average, and where rents are rising. The ongoing shortfall of affordable housing would have real consequences, either in terms of homelessness or people living in unsuitable accommodation. In the context of paragraph 8 of the Framework, such a shortfall and the likely inadequate future supply fails to ensure that a sufficient number and range of homes can be provided to meet the needs of present and future generations.
113. I understand that the Council's joint venture Hertsmere Living seeks to deliver affordable housing. While this is positive, it is unclear how many homes will be provided via this route in the short and medium-term. I also note that nearby Rossway Drive and Plomley Place provided around 71 affordable housing units. Notwithstanding this, the proposed development would deliver 40% affordable housing, in excess of CS policy CS4's requirement of 35% in this location, equating to up to 124 affordable homes. This would deliver over double Hertsmere's net annual average of affordable homes. In light of the extent of the gap between need for and provision of affordable housing, I afford this very substantial weight.
114. Turning to the matter of self and custom house building, the proposed development would include approximately 10 serviced plots secured by legal

¹⁴ Appeal APP/N1920/W/22/3311193, decision issued 25 May 2023.

agreement. Under the Self Build and Custom Housebuilding Act 2015, local authorities are required to keep a register of those seeking to acquire serviced plots in the area for their own self-build and custom house building. They are also subject to duties under the Act to have regard to this and to give enough suitable development permissions to meet the identified demand.

115. The Framework includes the requirement to plan for the needs of self and custom builders and is supported by the PPG, which advises that local authorities should use the demand data from registers, supported by additional data from secondary sources, to understand and consider future need for this type of housing in their area¹⁵. There is no adopted local planning policy for self and custom house building. The main parties agree in the Self-Build and Custom Housebuilding SOCG that such provision is an important part of the Government's strategy to resolve the housing crisis.
116. Around 80 names are on the Council's register, including associations. Doubt has been cast on public awareness of the register; the risk of demand being underestimated; robustness of assessment and review; use of secondary data; whether permissions have been appropriately recorded as and restricted to self and custom-building; and whether the statutory duty is met. Though some progress has been made with the delivery of plots, I concur with these doubts and consider that there would be substantial unmet need for this form of housing. I therefore attribute the provision of up to 10 serviced plots for self and custom-building substantial weight.
117. Paragraph 81 of the Framework asserts that planning policies and decisions should help create the conditions in which businesses can invest, expand and adapt. Significant weight should be placed on the need to support economic growth and productivity. The proposed development would deliver temporary economic benefits during construction and longer-term economic benefits. Temporary benefits would include some 342 direct and indirect construction jobs and wider economic output resulting from those jobs. Over the longer-term, economically active residents would contribute to the success of the local and wider economy in terms of economic output and commercial expenditure. I afford the economic benefits of the proposed development significant weight.
118. A net biodiversity gain of 20.33% habitat units, 39.42% hedgerow units and 12.41% river units is committed to by condition. Paragraph 180 of the Framework currently indicates opportunities to improve biodiversity in and around developments should be integrated as part of their design, especially where this can secure measurable net gains for biodiversity. The Environment Act 2021 requires 10% biodiversity net gain, but has not yet come into use. Other appeal decisions¹⁶ have given differing weight to biodiversity net gain. However, given the extent to which biodiversity net gain would exceed 10%, I afford this moderate weight.
119. DHLP allocation B1 included a new primary school, but this did not move forward as the DHLP was set aside. The proposed development includes land for the primary school which is secured via planning obligation. HCC forecasting

¹⁵ Paragraph 57-011-20210208 What is the relationship between the register and the Strategic Housing Market Assessment?

¹⁶ Including Appeal APP/B1930/W/21/3279463, decision issued 31 January 2022; Appeal APP/V1505/W/22/3296116, decision issued 11 November 2022; and Appeal APP/X0415/W/22/3303868, decision issued 8 March 2023.

indicates that additional primary school capacity is unlikely to be required within the next five years, with demand being absorbed by other local schools. However, the proposed development is considered by HCC to contribute to additional cumulative demand locally, the scale of which will be dependent upon the Local Plan's progress. This is something of a paradox. I consider that it has not been demonstrated at this point that the new school is necessary. I give the provision of land for the primary school only moderate weight.

120. The proposed development would include delivery of a package of sustainable transport measures, secured by planning obligation. This includes a contribution of £1,397,121 for a 30 minute frequency bus service between new bus stops adjacent to the site, and Watford Junction and Borehamwood stations for a five year period; £40,000 towards personalised travel planning; £648,939 for cycling and walking routes; £30,000 for updating school travel plans for a number of nearby schools; sustainable travel vouchers; travel planning and travel plan monitoring for the proposed development. Many of these measures mitigate the proposed development's effects and are necessary, but I consider that the bus service provision and the enhancement of cycling and walking routes would also represent benefits for the wider local community. I give these benefits moderate weight.
121. Paragraph 126 of the Framework refers to the creation of high quality, beautiful and sustainable buildings and places as being fundamental to what the planning and development process should achieve. While the appellant is committed to delivering a high quality development and a condition requires a site-wide design code, I consider high quality design to be an essential tenet of development. Accordingly, this is not a benefit and is neutral in weight.
122. The proposed development would have a mobility hub, secured by planning obligation. This would include a café, reading area, shared office space, sustainable transport information, a bike stop, electric vehicle charging and cycle parking, and parcel drop off and collection. This is agreed by the main parties as being of moderate weight. I see no reason to disagree.
123. The main parties are in agreement that significant levels of accessible open space should have moderate weight. I concur with this finding. However, enhanced access to the countryside and the enrichment of blue/green infrastructure would provide no more than a limited benefit over and above the provision of open space. I give this limited weight.
124. Reference has been made to sustainable building measures such as electric vehicle charging, and use of insulation, air source heat pumps, and photovoltaic panels above Building Regulations. As electric vehicle charging is adequately covered by Building Regulations, I discount this as a benefit, apart from the additional charging offered within the mobility hub above. With regard to the other sustainable building measures, I afford these limited weight in the absence of detail in what is an outline application.

Planning obligations

125. I have only addressed the planning obligations to ascribe weight to the benefits of other considerations. Given my findings below, it has not been necessary to examine the planning obligations any further.

Whether any harm to the Green Belt and any other harm, is clearly outweighed by other considerations, so as to amount to the very special circumstances necessary to justify the proposed development

126. Paragraph 148 of the Framework states that when considering any planning application, local planning authorities should ensure that substantial weight is given to any harm to the Green Belt. 'Very special circumstances' will not exist unless the potential harm to the Green Belt by reason of inappropriateness, and any other harm resulting from the proposal, is clearly outweighed by other considerations.
127. For this appeal, substantial harm would arise from inappropriateness, the significant reduction in openness, and conflict with two of the five Green Belt purposes, though the identified conflict with the purposes would be very limited and modest. These are three important elements contributing to the substantial weight to the actual and definitional harm to Green Belt. Though the Council chose to, I have not sought to apply a sliding scale to any specific level of substantial weight.
128. A Court of Appeal judgment¹⁷ has confirmed that the interpretation given to any other harm in what is now paragraph 148 of the Framework is such that it is not restricted to harm to the Green Belt. There would be significant harm to the character and appearance of the area and very substantial harm in relation to whether the site is in a suitable location with regard to local and national policies relating to flood risk.
129. The other considerations are weighted as follows: very substantial weight for the provision of both market and affordable housing; substantial weight for self and custom-build housing; significant weight for economic benefits; moderate weight for biodiversity net gain, the provision of land for the primary school, the package of sustainable transport measures, the mobility hub, and significant levels of accessible open space; limited weight to enhanced access to the countryside, the enrichment of blue/green infrastructure, and sustainable building measures. High quality design is neutral in weight.
130. I have had regard to the other considerations. However, these do not clearly outweigh the harms that I have identified. Consequently, the very special circumstances necessary to justify the proposed development do not exist. The proposed development would therefore conflict with CS Policy SP1 and CS13, SADM Policy SADM26, and the requirements of chapter 13 of the Framework which have been summarised above.
131. The main parties agree that there is no five-year housing land supply, although they disagree on the extent of the shortfall. The lack of five-year housing land supply indicates that paragraph 11 (d) of the Framework applies and the policies which are most important for determining the application are out-of-date. CS Policy SP2 sets out similar requirements. I have had regard to a legal judgment¹⁸ which confirms that where there are relevant development plan policies, but the most important for determining the application are out-of-date, planning permission should be granted (subject to section 38(6) of the 2004 Act) unless either limb (i) or limb (ii) is satisfied. The application of each limb is essentially a matter of planning judgment for the decision-maker.

¹⁷ SSCLG & Others v Redhill Aerodrome Ltd [2014] EWCA Civ 1386

¹⁸ Monkhill Ltd v SSHCLG & Waverley Borough Council [2019] EWHC 1993 (Admin)

132. In this instance, it is necessary to consider limb (i) of paragraph 11 (d) and footnote 7 of the Framework. For footnote 7 purposes in this appeal, the relevant policies within the Framework are those pertaining to land designated as Green Belt and areas at risk of flooding. These policies provide clear reasons for refusal of the appeal. As the Monkhill judgment confirms, where more than one footnote 6 policy is engaged (now footnote 7), limb (i) is satisfied, and the presumption in favour of sustainable development overcome, where the individual or cumulative application of those policies produces a clear reason for refusal. The presumption in favour of sustainable development is overcome in this appeal.
133. Despite the proposed development's merits, the very special circumstances do not clearly outweigh the conflict with the development plan and national policy in the Framework with regard to the totality of harm. In conclusion, the proposal would conflict with CS Policies SP1, SP2, CS12, CS13 and CS16, SADM Policies SADM11, SADM14, and SADM26, and paragraphs 148, 162, and 174 of the Framework, as set out above. As such, the appeal fails.

Conclusion

134. For the reasons set out above, the appeal should be dismissed and planning permission should be refused.

Joanna Gilbert

INSPECTOR

Appearances

For the Council

Emmaline Lambert, Counsel

Instructed by Mr Harvey Patterson,
Head of Legal Services, Hertsmere
Borough Council

She called:

James Dale

Hertfordshire County Council

Georgia O'Brien MA

Senior Planning Officer, Hertsmere
Borough Council

Grace Middleton MA

Senior Planning Officer, Hertsmere
Borough Council

Peter Radmall MA B.Phil CMLI

Peter Radmall Associates

Martin Ross BA PGDip

Senior Planning Officer, Hertsmere
Borough Council

Matthew Stimson

Shoosmiths

Charlie Thompson

Growth and Infrastructure,
Hertfordshire County Council

David Uncle

Hertfordshire County Council

Katherine Waters MSc BSc C.WEM
MCIWEM

Technical Director, WSP

Ross Whear BA (Hons) MA (Urban
Design)

Head of Planning and Economic
Development, Hertsmere Borough
Council

Daley Wilson PGDip

Senior Planning Officer, Hertsmere
Borough Council

For the Appellant

Zack Simons and Isabella Buono,
Counsel

Instructed by Mrs Kathryn Ventham,
Director, Stantec

They called:

Nicole Cameron

Solicitor, Cripps

Patrick H Clark BA MA Lsc. Arch. CMLI

Landscape Planning Associate Director,
Stantec

Caroline Featherston BSc (Hons) MSc
MRTPI

Planning Associate, Stantec

Nicholas Martin Paterson-Neild BA
(Hons) MPhil MRTPI

Director, Stantec

Andrew Moger BA (Hons) MA MRTPI

Director, Tetlow King Planning

Daniel Simpson BSc PhD CEcol

Director, Aspect Ecology

James Stacey BA (Hons) Dip TP MRTPI

Managing Director, Tetlow King
Planning

Matt Thomas MSc FCILT FCIHT

Director, Vectos

Kathryn Ventham BSc (Hons) MSc
MRTPI

Director, Stantec

Colin Whittingham BSc (Hons) MSc
MCIWEM C.WEM PIEMA

Director, LDE division of RSK

Interested Parties

Maxie Allen

Councillor, Hertsmere Borough Council

Daren Nathan

Local resident and member of Little
Bushey Community group

Chris Shenton

Councillor, Hertsmere Borough Council

Andrew Williams

Local resident and member of Little
Bushey Community group

Documents submitted during and after the Inquiry

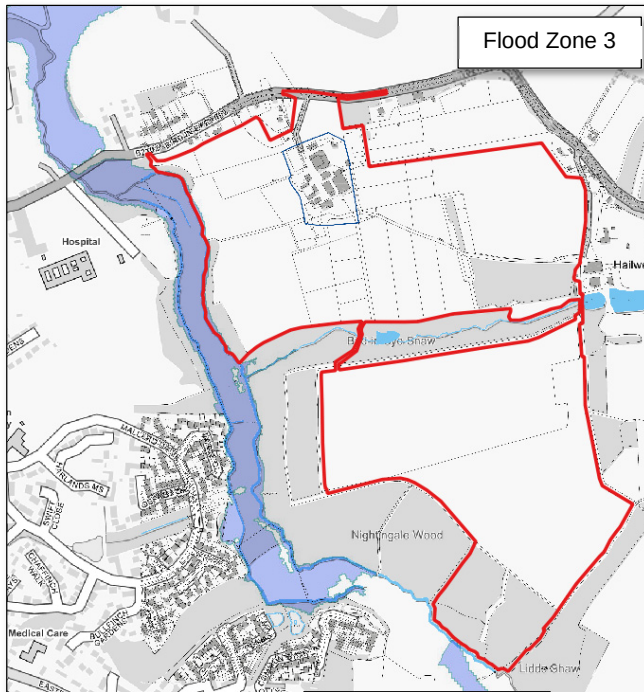
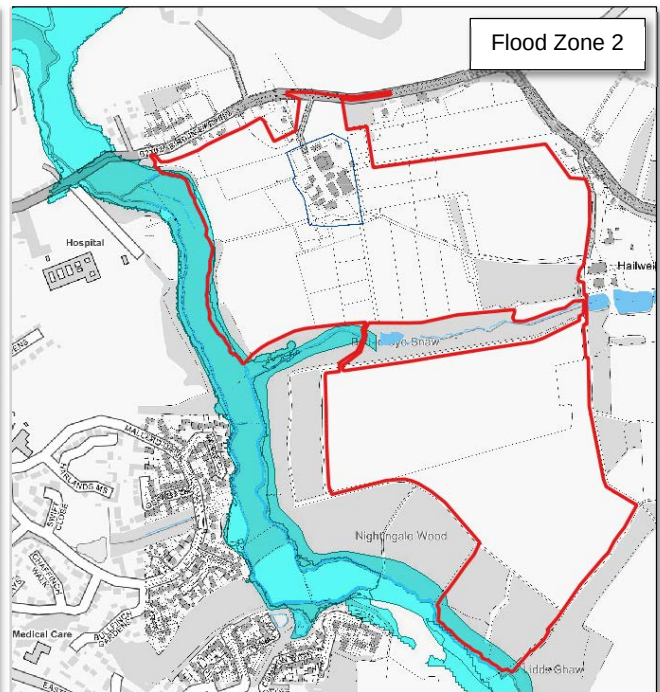
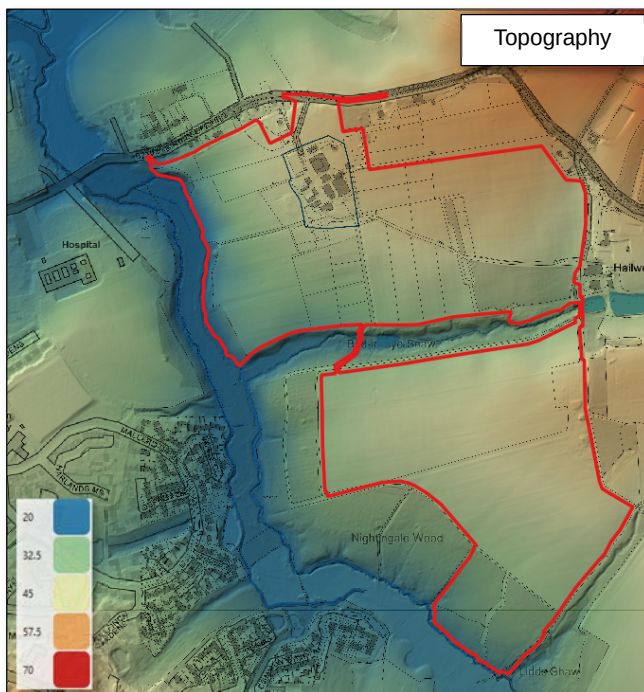
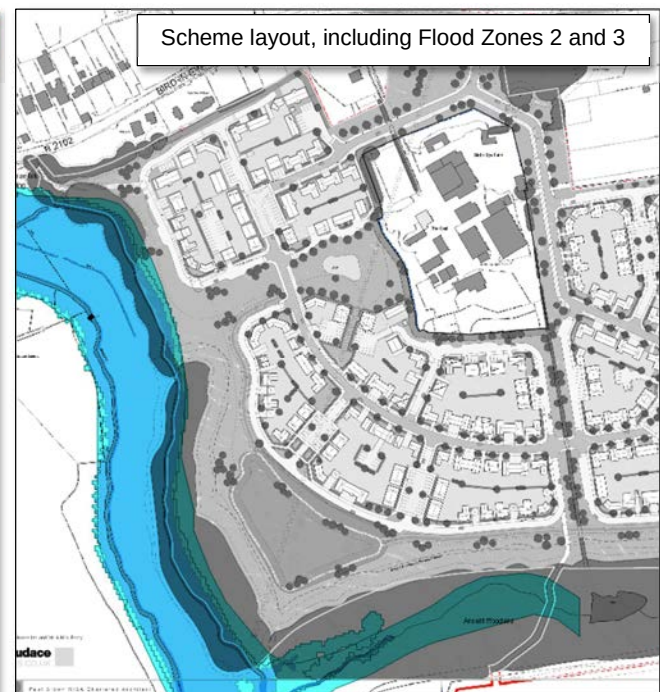
- ID1: Transport and Highways Statement of Common Ground between Redrow Plc and HCC, May 2023 (v3)
- ID2: Appellant's Opening and List of Appearances
- ID3: Council's Opening
- ID4: Housing Land Supply Statement of Common Ground, May 2023, including Disputed Sites List
- ID5: Self-Build and Custom Housebuilding Statement of Common Ground, 9 May 2023
- ID6: Affordable Housing – Statement of Common Ground, 9 May 2023
- ID7: Statement of Common Ground – Flood Risk and Drainage, May 2023
- ID8: Schedule of Draft Conditions
- ID9: Transport and Highways Statement of Common Ground between Redrow Plc and HCC, May 2023 (v4)
- ID10: Hertsmere Borough Council CIL Compliance Statement Addendum
- ID11: Draft planning obligation by deed of agreement between Redrow Homes Limited and HCC, received on 16 May 2023
- ID12: Draft planning obligation by unilateral undertaking by Redrow Homes Limited in favour of Hertsmere Borough Council, received on 16 May 2023
- ID13: Appeal decision APP/D2320/W/20/3247136, Land at Pear Tree Lane, Euxton, Chorley
- ID14: Email dated 17 May 2023 from the Council with regard to a proposed condition to remove permitted development rights
- ID15: Flood Risk Sequential Test and Exception Test, May 2023
- ID16: Land at Little Bushey Lane, Bushey: Proof of Evidence on Sequential Test Matters of Caroline Featherston MRTPI
- ID17: Rebuttal Proof of Evidence and Appendices A - E– Sequential Test (Planning) of Georgia O'Brien MA
- ID18: Rebuttal Proof of Evidence and Appendix A – Sequential Test (Flooding) of Katherine Waters MSc BSc C.WEM MCIWEM
- ID19: Supplementary Proof of Evidence Addendum – Sequential Test (Planning) and Addendum Proof - Appendix A of Martin Ross BA PGDip
- ID20: Supplementary Proof of Evidence Addendum – Sequential Test (Planning) and Addendum Proof - Appendix A of Martin Ross BA PGDip - Updated
- ID21: Draft conditions received 26 June 2023
- ID22: Draft planning obligation by unilateral undertaking by Redrow Homes Limited in favour of Hertsmere Borough Council, received on 27 June

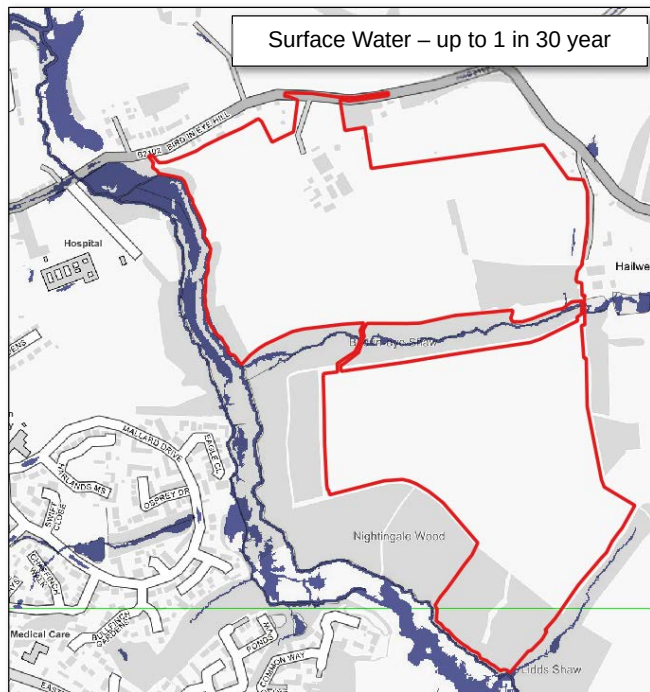
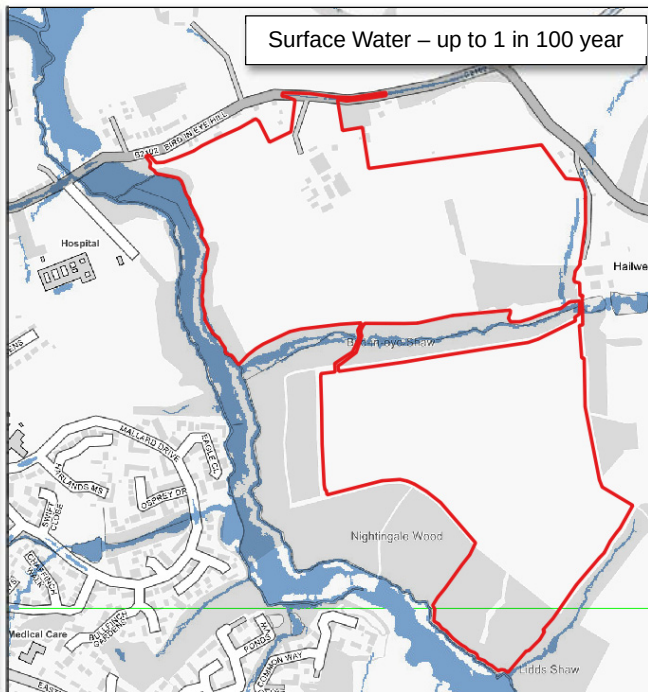
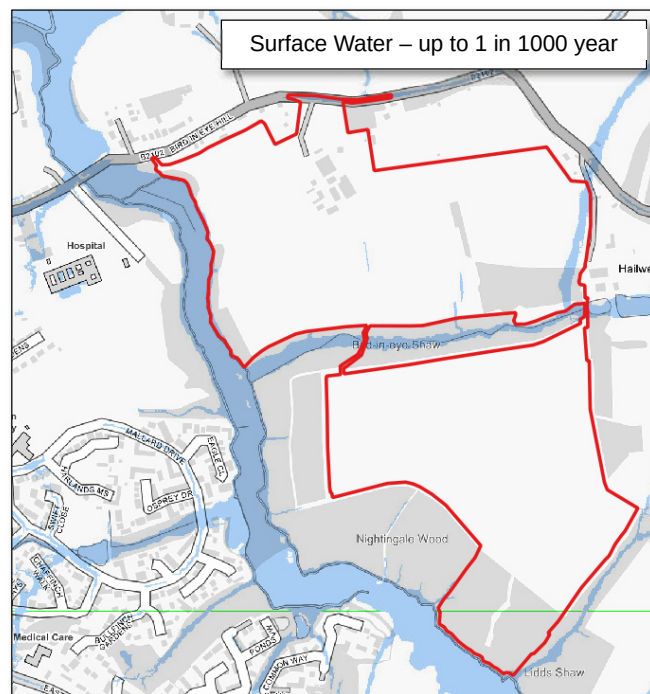
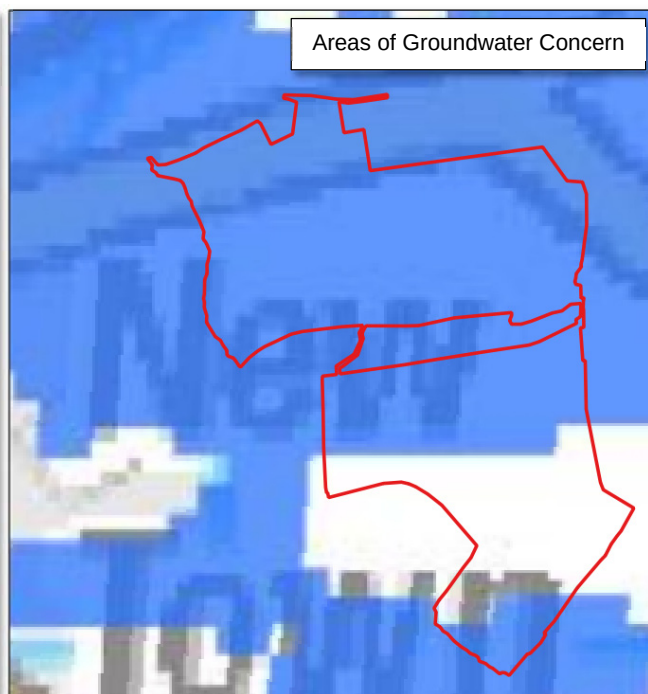
2023

- ID23: Appeal decision APP/N1920/W/22/3311193, Land adjacent and to the rear of 52 Harris Lane, Shenley WD7 9EG
- ID24: Flood Risk Sequential Test Statement of Common Ground, June 2023
- ID25: Statement made by Councillor Maxie Allen
- ID26: Appeal decision APP/D0121/W/22/3313624 Land at Lynchmead Farm, Ebdon Road, Wick St Lawrence, Weston-super-Mare BS22 9NY.
- ID27: Revised statement made by Councillor Maxie Allen
- ID28: Statement made by Councillor Chris Shenton
- ID29: Planning Benefits Table
- ID30: Start to Finish: What factors affect the build-out rates of large scale housing sites? Second Edition, Lichfields, February 2020
- ID31: Briefing Note prepared by RSK – Flood Risk and Drainage, 3 May 2023
- ID32: 2014 Planning Practice Guidance Flood risk and coastal change
- ID33: Draft planning obligation by unilateral undertaking by Redrow Homes Limited in favour of Hertsmere Borough Council, received on 5 July 2023
- ID34: Final schedule of planning conditions, received on 6 July 2023
- ID35: Ms O'Brien's meeting notes for meeting between appellant, Council and LLFA, dated 22 February 2023
- ID36: Appellant's costs application, received on 6 July 2023
- ID37: HCC's response in respect of transfer of part of the registered title, received on 6 July 2023
- ID38: Draft planning obligation by deed of agreement between Redrow Homes Limited and HCC, and its appendices, received on 6 July 2023
- ID39: Education Position Statement, dated 24 February 2023
- ID40: Draft TP1 Form with comments from HCC, received on 7 July 2023
- ID41: Draft TP1 Form – clean version from appellant, received 7 July 2023
- ID42: Email from HCC in respect of condition on reserved matters for the primary school, including a committee report for 21/00356/FPM Land West of Stevenage, received 7 July 2023
- ID43: Email from Council agreeing to amended main issue on flood risk, received 7 July 2023
- ID44: Email from appellant agreeing to amended main issue on flood risk, received 7 July 2023
- ID45: Draft TP1 Form – clean version from HCC, received 7 July 2023
- ID46: Email from HCC regarding planning obligation progress, received 10 July 2023

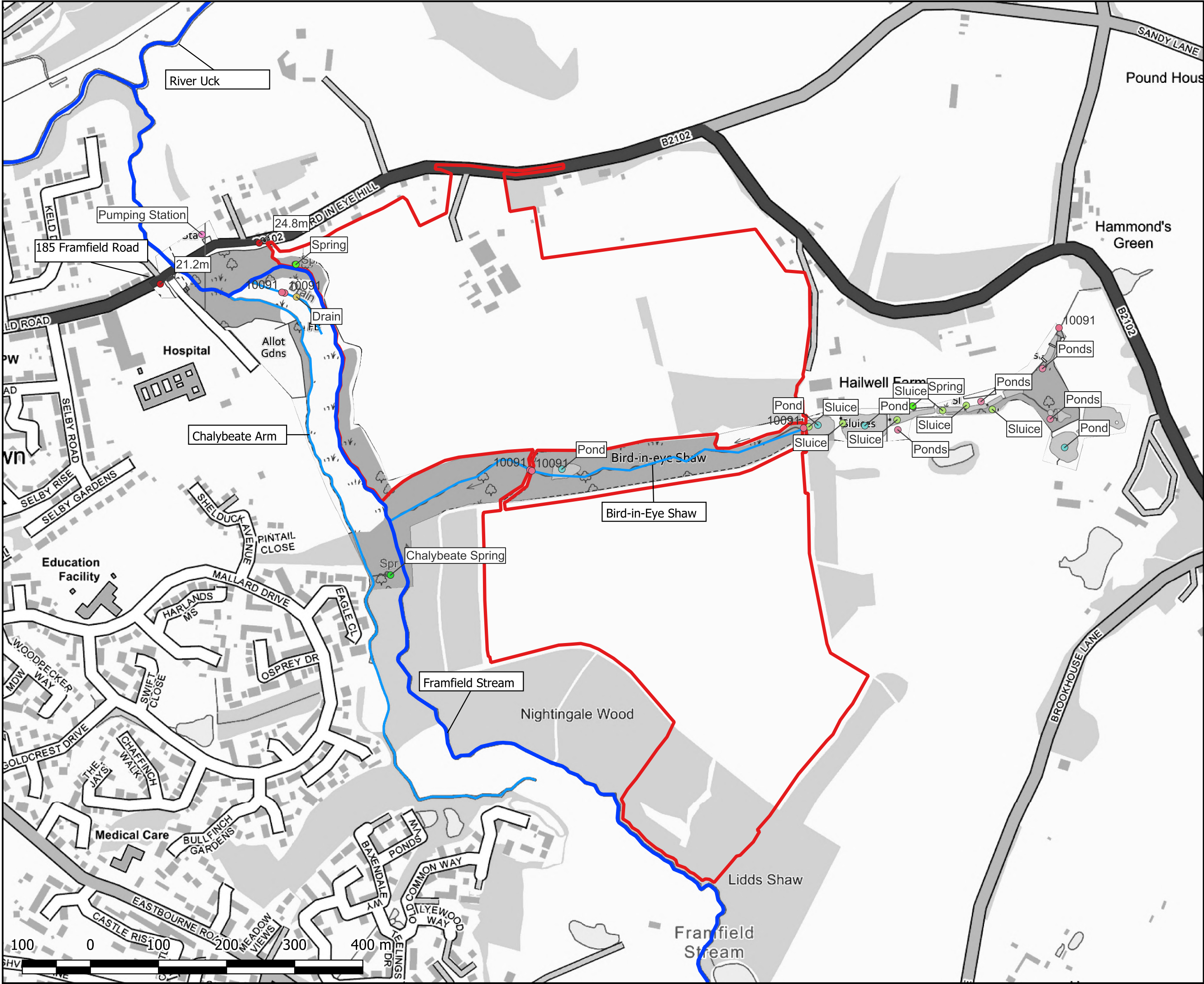
- ID47: Council's closing submissions
- ID48: Appellant's closing submissions
- ID49: Completed planning obligation by unilateral undertaking by Redrow Homes Limited in favour of Hertsmere Borough Council, received on and dated 13 July 2023
- ID50: Email from appellant regarding company name change for members of the appellant's team, received 13 July 2023
- ID51: Completed planning obligation by deed of agreement between Redrow Homes Limited and HCC, received on and dated 13 July 2023
- ID52: Council's response to appellant's costs application, including appendices, received 14 July 2023
- ID53: Appellant's reply on costs application, received 17 July 2023

Appendix A.2 – Flood risk mapping from various sources





Appendix A.3 – Site context in relation to the surrounding watercourses



TITLE

Map of Watercourses and Key Structures

LEGEND

- Site Boundary
- Main River
- Ordinary Watercourses

NOTES

1. This drawing contains Ordnance Survey data © Crown copyright and database copyright 2023.

2. All dimensions are in metres unless otherwise stated

3. All heights are in metres Above Ordnance Datum Newlyn (mAODN) unless otherwise stated

This map is reproduced from Ordnance Survey material with the permission of Ordnance Survey on behalf of the controller of His Majesty's Stationary Office © Crown copyright. Unauthorised reproduction infringes Crown copyright and may lead to prosecution or civil proceedings.

herrington

CONSULTING LIMITED

Canterbury (HQ): Unit 6-7 Berham Business Park, Elham Valley Road, Canterbury, Kent CT14 6DQ
London: Unit 52.11, Woolyard, 52 Bermondsey Street, London, SE1 3UD

REV	DESCRIPTION	DATE
1	1st issue	14/08/2023

CLIENT

Ms Kassie Smith

PROJECT

3774 - Bird in Eye Hill

SCALE

1:5024 @ A3

PROJECT No.

3774

INITIALS

AW

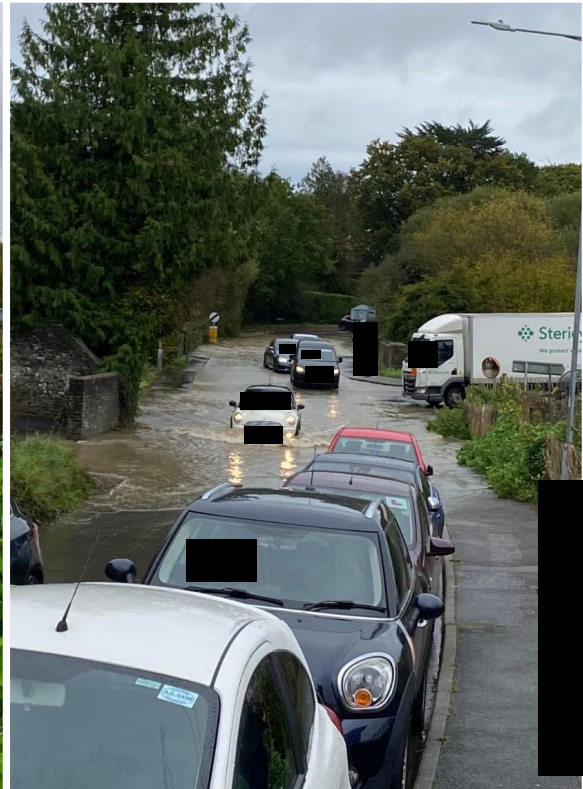
CHECKED BY

SMB

DRAWING No.

Appendix A.3

Appendix A.4 – Photographs of B2102/Framfield Road flooding in November 2022





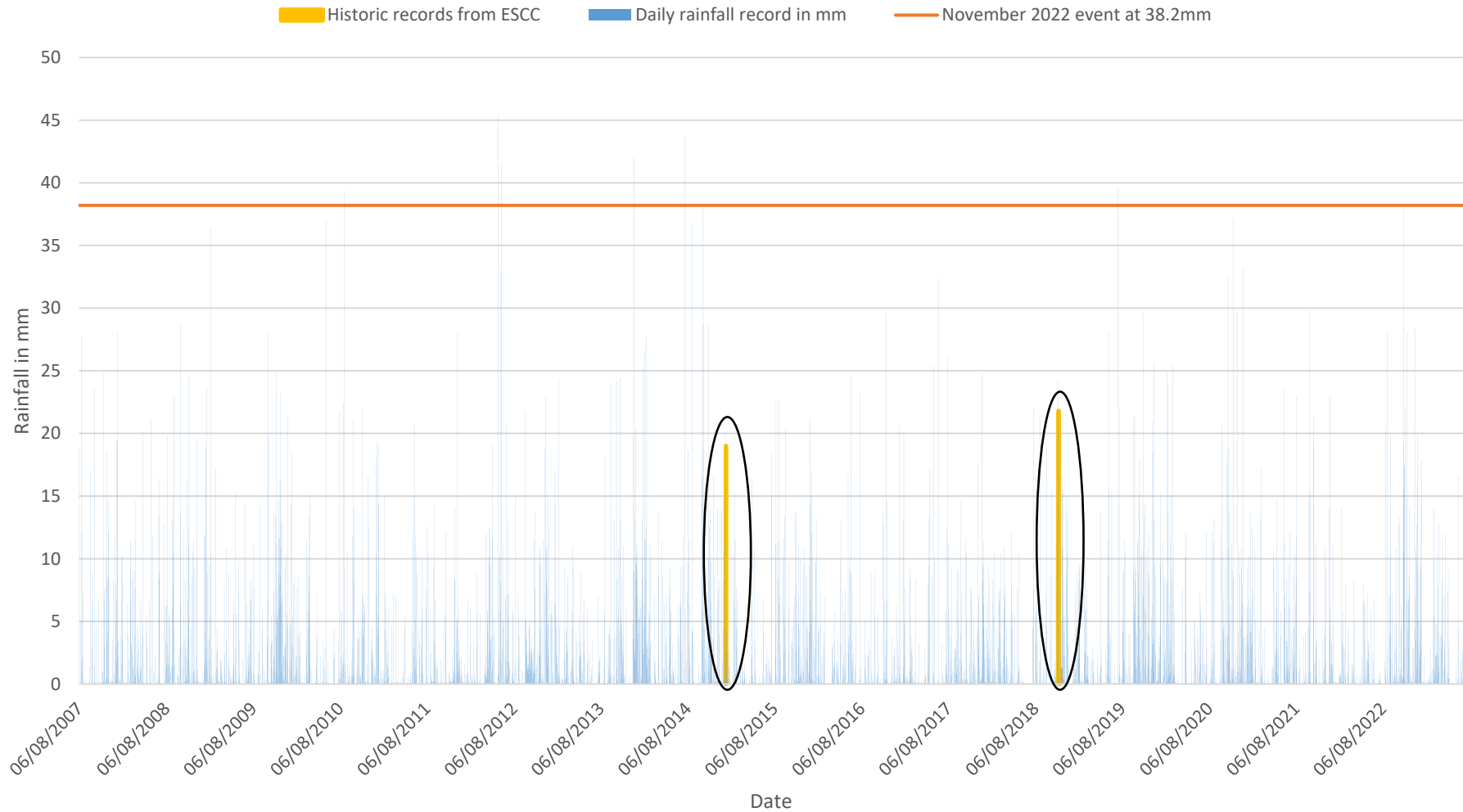
Appendix A.5 – Information on Rainfall Gauging Stations

Site location of nearby rainfall gauging stations



Site location of nearby rainfall gauging stations (taken from Defra's Hydrology Data Explorer - <https://environment.data.gov.uk/hydrology/explore>). Contains OS data © Crown copyright and database rights 2023.

Daily total Rainfall (mm) time series for Isfield from 06th August 2007 to 11th July 2023



Rainfall modelling FEH22

FEH13 FEH22

☐ Design Rainfall
☒ Event Rarity

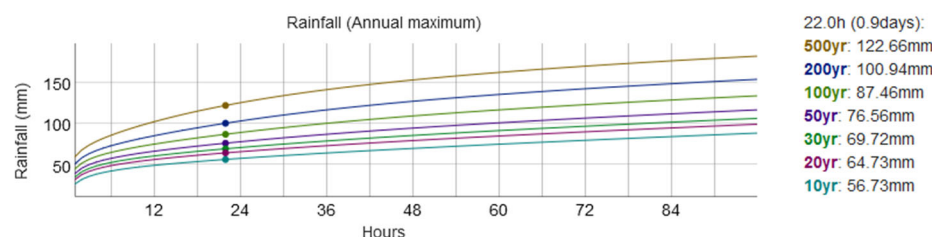
Duration * 11 Hours Sliding
 Depth * 41 mm
☒ Annual Max. ☐ Peaks over threshold

[Calculate](#) [Export](#)

Return period

4.8 years

A 11-hour rainfall (sliding) of 41 mm has a return period of 4.8 years on the annual maximum scale (equivalent to 4.28 years on the peaks-over-threshold scale).



[Save graph as image](#)

[Close](#)

Rainfall modelling FEH22 for the rainfall event on the 3rd November 2023 at Isfield rainfall gauging station.

Design-rainfall¶

The depth-duration-frequency (DDF) model provided with the FEH (1999) was replaced in 2015 with the FEH 2013 (FEH13) rainfall model. (Stewart and others, 2013). Both the FEH99 and FEH13 rainfall statistics are available for catchments via the FEH Web service. They enable the estimation of design rainfall depths for any location in the UK or the return period of an observed rainfall.¶

Extract from the EA's "LIT 11832 - Flood Estimation Guidance", Section 4.3 – Rainfall runoff approaches, page 97 of 131.

The DDF models can be used to derive design storm inputs for the ReFH2 rainfall-runoff package or to estimate the rarity of observed rainfall events at individual points or over a catchment. The DDF model is widely used for applications such as flood risk assessment, reservoir flood safety appraisal and drainage design throughout the UK.

The FEH22 and FEH13 models retained the basic index-flood approach of the FEH99 model, i.e. the rainfall frequency curve is derived by multiplying an index variable specific to the site of interest by a regionally derived growth curve, but the main advances are:

A key feature of the modelling procedures is the use of local data wherever possible. Data from smaller networks of rain gauges are used to estimate the frequency curve for shorter return periods, while more spatially extensive networks are drawn into the analysis to define the frequency characteristics for longer return periods. The FEH22 and FEH13 DDF models were fitted to the outputs from the revised FORGEX procedure at each point on a 1 km grid of the UK for a number of key durations. The model ensures internal consistency in the resulting frequency estimates, i.e. that rainfall depths for any duration increase with increasing return period, and that rainfall depths for any return period increase with increasing duration. It also allows extrapolation to longer return periods than those estimated for the rarest events in the calibration dataset. The model is based on a weighted total of two gamma distributions, each of which is parameterised by duration-dependent equations intended to minimise the difference between the fitted model curves and the output FORGEX lines. The final step in the modelling procedure is smoothing in space and across durations to avoid inconsistencies in the results.

Extracts from the FEH Web Service, User Guide (DDF Science),

<https://fehwebdocs.hydrosolutions.co.uk/docs/DDF-Science/Overview/>

Appendix A.6 – Historic flood information provided by ESCC

Date	Description
12/10/2000	Fluvial flooding in Uckfield
14/01/2015	Gulley blocked causing flooding during heavy rainfall at road junction following bend
12/11/2018	Heavy rain causing large volumes of standing water at the bottom of Bird in Eye Hill
19/11/2018	Bird in Eye Hill, 20m before hospital junction, Uckfield.

Subject: FW: BIES, Uckfield
Attachments: B2102 Flood Risk.xlsx; Bird in Eye Hill Flood History.pdf

From: Kal Kamboh <Kal.Kamboh@eastsussex.gov.uk>

Sent: Wednesday, August 2, 2023 9:52 AM

To: [REDACTED]

Cc: [REDACTED]

Subject: FW: BIES, Uckfield

Hi Richard,

I have been provided with some info. Please let me know if you have any questions regarding this so I can pass them on. I was surprised there is nothing more recent tbh.

regards

Ms Kal Kamboh

Strategic Sites Transport Advisor
Transport Development Control
Communities, Economy and Transport

01273 482287 | 07701394 524

eastsussex.gov.uk



From: Andrew Goswell <Andrew.Goswell@eastsussex.gov.uk>

Sent: Wednesday, August 2, 2023 9:40 AM

To: Kal Kamboh <Kal.Kamboh@eastsussex.gov.uk>

Cc: Nick Claxton <Nick.Claxton@eastsussex.gov.uk>

Subject: RE: BIES, Uckfield

Good morning Kal,

Please find attached a spreadsheet and a map of the records of flooding in the specified area.

Kind regards,

Andrew

Andrew Goswell

Flood Risk Technician
Flood Risk Management

07895 187802
eastsussex.gov.uk



From: Nick Claxton <Nick.Claxton@eastsussex.gov.uk>
Sent: Tuesday, August 1, 2023 5:42 PM
To: Kal Kamboh <Kal.Kamboh@eastsussex.gov.uk>
Cc: Andrew Goswell <Andrew.Goswell@eastsussex.gov.uk>
Subject: RE: BIES, Uckfield

Hi Kal

We can knock it together – when do you need it?

Thaks

Nick

From: Kal Kamboh <Kal.Kamboh@eastsussex.gov.uk>
Sent: Tuesday, August 1, 2023 2:20 PM
To: Nick Claxton <Nick.Claxton@eastsussex.gov.uk>
Subject: FW: BIES, Uckfield

Hello Nick,
I wonder if anyone in you team can assist with providing information for an impending PI for the 290 dwelling devt at Bird in Eye South, Bird in Eye Hill B2102, near the hospital access please?

Thank you

Ms Kal Kamboh
Strategic Sites Transport Advisor
Transport Development Control
Communities, Economy and Transport

01273 482287 | 07701394 524
eastsussex.gov.uk



From: [REDACTED]
Sent: Tuesday, August 1, 2023 2:16 PM
To: Kal Kamboh <Kal.Kamboh@eastsussex.gov.uk>
Cc: rnew@gtacivils.co.uk
Subject: RE: BIES, Uckfield

Hi Kal

Our flooding witness has asked if you would be able to help with any recorded information on past flood events on the B2102 (Framfield Road/Bird in Eye Hill)? If you have a spreadsheet with the information recorded that would be useful.

Many thanks.

Regards

[REDACTED]

[REDACTED]



The Close, 44 Over Lane, Almondsbury,
South Gloucestershire. BS32 4BW

T: [REDACTED]
E: [REDACTED]
W: mileswhitetransport.co.uk

From: Richard White
Sent: Tuesday, August 1, 2023 12:12 PM
To: Kal Kamboh <Kal.Kamboh@eastsussex.gov.uk>
Cc: rnew@gtacivils.co.uk
Subject: BIES, Uckfield

Hi Kal

I have just had a call/meeting with Mary Cook to discuss my draft proof and there are some changes that I need to make over the next week or so. I will be issuing a revised draft proof to Mary by the close of business next Monday (8th) and should have a version with Mary's comments (track changed rather than clean) that I can share with you and Roger by the middle of next week, which I hope is OK.

Two things that came up in my discussion with Mary that you may be able to help with below:

1. Can you send me the most recent five years of accident data for Framfield Road/Bird in Eye Hill that ESCC have please? I have CrashMap data but this would be good to see as well?
2. Do you have anything on ESCC's LTP4 that you can share with me (I have seen on your website that further consultation is planned in the autumn)?

Regards

[REDACTED]



The Close, 44 Over Lane, Almondsbury,
South Gloucestershire. BS32 4BW

T: [REDACTED]
E: [REDACTED]
W: mileswhitetransport.co.uk

This message is intended for the use of the addressee only and may contain confidential or privileged information. If you have received it in error please notify the sender and destroy it. You may not use it or copy it to anyone else.

E-mail is not a secure communications medium. Please be aware of this when replying. All communications sent to or from the County Council may be subject to recording and/or monitoring in accordance with relevant legislation.

Although East Sussex County Council has taken steps to ensure that this e-mail and any attachments are virus free, we can take no responsibility if a virus is actually present and you are advised to ensure that the appropriate checks are made.

You can visit our website at <https://www.eastsussex.gov.uk>

Appendix A.7 – R&D Output FD2320/TR2 and Supplementary Note

SUPPLEMENTARY NOTE ON FLOOD HAZARD RATINGS AND THRESHOLDS
FOR DEVELOPMENT PLANNING AND CONTROL PURPOSE
– Clarification of the Table 13.1 of FD2320/TR2 and Figure 3.2 of FD2321/TR1.

Suresh Surendran and Geoff Gibbs (Environment Agency),
Steven Wade and Helen Udale-Clarke (HR Wallingford)
May 2008

Introduction

This document is a supplementary note to reconcile information provided in the ‘Flood Risks to People Methodology’ (FD2321/TR1¹) and the ‘Framework and Guidance for Assessing and Managing Flood Risk for New Development’ (FD2320/TR2²) reports about the Flood Hazard Rating. It has been produced because both PPS25 in England and TAN15 in Wales require that people should be appropriately safe around new development. The document emphasises that for FRAs and FCAs at all levels to inform development allocations and proposals the simplified approach of FD2320 with regard to flood hazard rating should be used rather than the approach in FD2321. Although the final version of FD2321/TR1 post-dates FD2320/TR2, the work presented actually pre-dates the guidance in FD2320/TR2. This supplementary guidance is issued for those involved in development planning and control and to clarify the detail or difference of the Table 13.1 of FD2320/TR2 and Figure 3.2 of FD2321/TR1.

FD2321/TR1 was a research project based on the detailed literature review and analysis of empirical evidence related to flood hazard, derived mainly from theoretical assumptions and some basic laboratory experiments. Factors that affected flood hazard and vulnerability were combined in a form of multi-criteria analysis that was used to identify the hot-spots and broadly estimate the probability of people seriously harmed and fatalities during the event of a flood. The multi-criteria method was calibrated to actual events, validated using data from seven flood events and shown to work well. The FD2321 (Risk to people) methodology illustrates the fundamental concepts and demonstrate how the approach could be used for different applications - it did not set a policy for flood hazard thresholds.

(Nevertheless there are a number of assumptions used in the FD2321 methodology, particularly with respect to the impact of debris and people’s behaviour during flood events. There is a requirement for further research to collate more evidence on flood hazard, particularly the impacts of debris, and vulnerability in order to refine assumptions made in the flood hazard calculations, flood hazard thresholds and risks to people guidance. The study recommend more laboratory and field based tests on the impact of physical water quality aspect such as debris, mudflow; chemical and biological water quality that cause seriously harm or fatalities to people.)

¹ Defra and Agency (2006) *The Flood Risks to People Methodology*, Flood Risks to People Phase 2, FD2321 Technical Report 1, HR Wallingford et al. did the report for Defra/EA Flood and Coastal Defence R&D Programme, March 2006.

(http://sciencesearch.defra.gov.uk/Document.aspx?Document=FD2321_3436_TRP.pdf)

² Defra and Agency (2005) *Framework and Guidance for Assessing and Managing Flood Risk for New Development*, Flood Risk Assessment Guidance for New Development, FD2320 Technical Report 2, HR Wallingford et al. did the report for Defra/EA Flood and Coastal Defence R&D Programme, October 2005. (http://sciencesearch.defra.gov.uk/Document.aspx?Document=FD2320_3364_TRP.pdf)

FD2320/TR2 (FRA guidance for new development) provides guidance that is a specific interpretation of the methodology developed under FD2321, within the context of development planning and control. Based on FD2320 consultation workshops, the project board (key users and experts) advised the project team to provide a simple methodology. Due to uncertainties and limitations related to estimating risks to people, FD2320 adopted a precautionary approach, particularly with respect to the selection of debris factors and flood hazard thresholds

Risk to People (Ninj)

$$\mathbf{Ninj} = \mathbf{Nz} \times \mathbf{Flood\ Hazard\ Rating} \times \mathbf{Area\ Vulnerability} \times \mathbf{People\ Vulnerability}$$

where,

Ninj (Risk to People) = number of injuries within a particular hazard 'zone';

Nz = number of people within the hazard zone (at ground/basement level);

Flood Hazard Rating = HR = function of flood depth/velocity (within the hazard zone being considered) and debris factor;

Area Vulnerability = function of effectiveness of flood warning, speed of onset of flooding and nature of area (including types of buildings); and

People Vulnerability = function of presence of people who are very old and/or infirm/disabled/long-term sick

Flood Hazard Rating (HR) and thresholds

The revised 'hazard rating' expression based primarily, on consideration to the direct risks of people exposed to floodwaters.

$$\mathbf{HR} = \mathbf{d} \times (\mathbf{v} + \mathbf{n}) + \mathbf{DF}$$

where, HR = (flood) hazard rating;

d = depth of flooding (m);

v = velocity of floodwaters (m/sec); and

DF = debris factor (0, 0.5, 1 depending on probability that debris will lead to a hazard)

n = a constant of 0.5

This final revised Flood Hazard Rating formula from the Flood Risks to People project is presented on page 10 (section 3.5) of FD2321/TR1. The formula is identical in both FD2320 and FD2321 reports.

Based on Table 3.2 of FD2321, the Figure 3.2 of FD2321 illustrates the "Hazard to People Classifications" as a function of depth, velocity and debris factor. Such categorisation and the look-up table with flood hazard threshold could be useful for a range of application as an initial indication of Risks to People.

In this case (Figure 3.2 of FD2321) the calculation takes a debris factor as zero

$$(\mathbf{HR} = \mathbf{d} \times (\mathbf{v} + \mathbf{0.5}) + \mathbf{0}).$$

However FD2321 strongly recommends the use of the debris factor and the formulas described in the Guidance Document for further calculation. The Table 3.1 of FD2321/TR1 (Table 1 of this note) suggests appropriate debris factors for different depths, velocities and the dominant land use.

Table 1: Guidance on debris factors for different flood depths, velocities and dominant land uses. (Source FD2321 Table 3.1):

Depths (d)	Pasture/Arable	Woodland	Urban
0 to 0.25 m	0	0	0
0.25 to 0.75 m	0	0.5	1
d>0.75 m and/or v>2	0.5	1	1

The way that Flood Hazard Rating and thresholds have been presented in Table 13.1 in FD2320/TR2 compared to Figure 3.2 of FD2321/TR1

A concern was raised in the FD2320 consultation workshops and by the FD2320 Project Board during discussions on FD2321, that the methodology was complex and the results presented in the Figure 3.2 of FD2321 were not reflecting the potential risk to people (as this table was of hazard rating for different depths and velocity without debris). There was a need for further work to include debris, area vulnerability and people vulnerability aspects. They requested a simpler single table to represent the risk to people.

For example Figure 3.2 of FD2321 did not reflect the fact that there is a risk from drowning even at low depths and velocities. In reality FD2321/TR1 recognises this but only in the subsequent “people vulnerability” calculation (risk to children, old, sick and disable). For still water up to 1.25m depth, the Figure 3.2 of FD2321/TR1 assumes that there is low hazard, if there are no debris or vulnerable group. However to avoid further calculation, but include the vulnerability aspect the Table 13.1 of FD2320 for still water with the depths between 0.25–1.25m were reclassified as “danger to some”, which was felt to be more appropriate for development planning and control, where users may make use of flood hazard without completing the more complex full calculations including people and area vulnerability.

Similarly Figure 3.2 of FD2321/TR1 shows that at the depth of 0.25m, if there is no debris then up to the flow velocity of 2.0 m/sec there would be low hazard. However FD2321/TR1 suggests the usage of an appropriate debris factor dependent on depth, velocity and the dominant land use. To make the process simpler (whatever the land use), FD2320/TR2 includes a default debris factor. In the Table 13.1 of FD2320/TR2 a debris factor of 0.5 has been applied for depths less than and equal to 0.25m and a debris factor of 1.0 has been used for depths greater than 0.25m. Therefore, in the Table 13.1 of FD2320/TR2 at the depth of 0.25m, up to the flow velocity of 0.30 m/sec is treated as low hazard.

Table 3.2 of FD2321/TR1 (Table 2 of this note) provides thresholds for classifying the hazard to people. In the FD2321/TR1 report the threshold between “danger for most” and “danger for all” is 2.5 and it was used as an initial indication of Risk to People (further calculation is recommended using the formulas). However as there is no further analysis in FD2320 but the Project Board decided that the threshold between “danger for most” and “danger for all” should be more precautionary and a Flood Hazard Rating of 2.0 is selected as a key threshold. i.e. In FD2321 the threshold for “danger for all” is 2.5 and it lowered to 2.0 in FD2320. Therefore, the Flood Hazard Rating between 2.0 to 2.5 in FD2320 is not classified as it is in FD2321.

Table 2: Hazard to People (Source Table 3.2 in FD2321/TR1)

Thresholds for Flood Hazard Rating $H = d \times (v + 0.5) + DF$		Degree of Flood Hazard	Description
FD2321	FD2320		
<0.75	<0.75	Low	Caution - "Flood zone with shallow flowing water or deep standing water"
0.75 - 1.25	0.75 - 1.25	Moderate	Dangerous for some (i.e. children) - "Danger: Flood zone with deep or fast flowing water"
1.25 - 2.5	1.25 - 2.0	Significant	Dangerous for most people - "Danger: flood zone with deep fast flowing water"
>2.5	>2.0	Extreme	Dangerous for all - "Extreme danger: flood zone with deep fast flowing water"

The final difference between Table 13.1 in FD2320/TR2 and Figure 3.2 of FD2321/TR1 is the use of smaller increments of depth, so that lower depths are presented more fully in FD2320/TR2. This was felt to be more helpful for identifying what might be judged as acceptable depending on site specific circumstances.

Conclusions

Table 13.1 of FD2320 and Figure 3.2 of FD2321 look very similar but there are significant differences (see Table 3 of this paper). Either Table/Figure can be used as the basis for assessing the risks to people associated with different flood depths velocities and debris factors.

Table 3: comparison of Table 13.1 of FD2320/TR2 and Figure 3.2 of FD2321/TR1

	In Table 13.1 of FD2320/TR2	In Figure 3.2 of FD2321/TR1
The depths above 0.25m	Danger for some, most or all	For still water, up to 1.25m the hazard is low (In addition to hazard rating further calculation to include vulnerability aspect is recommended)
Debris factor	Debris factor of 0.5 has been applied for depths $\leq 0.25m$ and a debris factor of 1.0 has been used for depths $\geq 0.25m$.	In this case a Debris factor of zero applied (in addition to this further calculation is recommended using debris factor and the formulas)
HR Thresholds for "Dangerous for all" hazard classification	>2.0 (precautionary due to uncertainties and to avoid further calculation as FD2321)	>2.5
Increments of depth	Small increments at lower depths	Every 0.25 m

Table 13.1 of FD2320/TR2 is a simple method applies the precautionary principle and uses suitable assumptions (so that there is no need for further calculations) for application in the development planning and control context (see Table 4 of this paper - an extended version of table 13.1).

This table is recommended for development planning and control use.

Table 4 – Hazard to People Classification using Hazard Rating ($HR = d \times (v + 0.5) + DF$) for (Source Table 13.1 of FD2320/TR2 - Extended version)

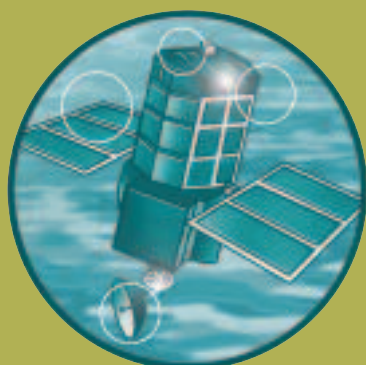
HR	Depth of flooding - d (m)												
	DF = 0.5				DF = 1								
Velocity v (m/s)	0.05	0.10	0.20	0.25	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	2.50
0.0	0.03 + 0.5 = 0.53	0.05 + 0.5 = 0.55	0.10 + 0.5 = 0.60	0.13 + 0.5 = 0.63	0.15 + 1.0 = 1.15	0.20 + 1.0 = 1.20	0.25 + 1.0 = 1.25	0.30 + 1.0 = 1.30	0.40 + 1.0 = 1.40	0.50 + 1.0 = 1.50	0.75 + 1.0 = 1.75	1.00 + 1.0 = 2.00	1.25 + 1.0 = 2.25
0.1	0.03 + 0.5 = 0.53	0.06 + 0.5 = 0.56	0.12 + 0.5 = 0.62	0.15 + 0.5 = 0.65	0.18 + 1.0 = 1.18	0.24 + 1.0 = 1.24	0.30 + 1.0 = 1.30	0.36 + 1.0 = 1.36	0.48 + 1.0 = 1.48	0.60 + 1.0 = 1.60	0.90 + 1.0 = 1.90	1.20 + 1.0 = 2.20	1.50 + 1.0 = 2.55
0.3	0.04 + 0.5 = 0.54	0.08 + 0.5 = 0.58	0.15 + 0.5 = 0.65	0.19 + 0.5 = 0.69	0.23 + 1.0 = 1.23	0.30 + 1.0 = 1.30	0.38 + 1.0 = 1.38	0.45 + 1.0 = 1.45	0.60 + 1.0 = 1.60	0.75 + 1.0 = 1.75	1.13 + 1.0 = 2.13	1.50 + 1.0 = 2.50	1.88 + 1.0 = 2.88
0.5	0.05 + 0.5 = 0.55	0.10 + 0.5 = 0.60	0.20 + 0.5 = 0.70	0.25 + 0.5 = 0.75	0.30 + 1.0 = 1.30	0.40 + 1.0 = 1.40	0.50 + 1.0 = 1.50	0.60 + 1.0 = 1.60	0.80 + 1.0 = 1.80	1.00 + 1.0 = 2.00	1.50 + 1.0 = 2.50	2.00 + 1.0 = 3.00	2.50 + 1.0 = 3.50
1.0	0.08 + 0.5 = 0.58	0.15 + 0.5 = 0.65	0.30 + 0.5 = 0.80	0.38 + 0.5 = 0.88	0.45 + 1.0 = 1.45	0.60 + 1.0 = 1.60	0.75 + 1.0 = 1.75	0.90 + 1.0 = 1.90	1.20 + 1.0 = 2.20	1.50 + 1.0 = 2.50	2.25 + 1.0 = 3.25	3.00 + 1.0 = 4.00	3.75 + 1.0 = 4.75
1.5	0.10 + 0.5 = 0.60	0.20 + 0.5 = 0.70	0.40 + 0.5 = 0.90	0.50 + 0.5 = 1.00	0.60 + 1.0 = 1.60	0.80 + 1.0 = 1.80	1.00 + 1.0 = 2.00	1.20 + 1.0 = 2.20	1.60 + 1.0 = 2.60	2.00 + 1.0 = 3.00	3.00 + 1.0 = 4.00	4.00 + 1.0 = 5.00	5.00 + 1.0 = 6.00
2.0	0.13 + 0.5 = 0.63	0.25 + 0.5 = 0.75	0.50 + 0.5 = 1.00	0.63 + 0.5 = 1.13	0.75 + 1.0 = 1.75	1.00 + 1.0 = 2.00	1.25 + 1.0 = 2.25	1.50 + 1.0 = 2.50	2.00 + 1.0 = 3.00	3.50	4.75	6.00	7.25
2.5	0.15 + 0.5 = 0.65	0.30 + 0.5 = 0.80	0.60 + 0.5 = 1.10	0.75 + 0.5 = 1.25	0.90 + 1.0 = 1.90	1.20 + 1.0 = 2.20	1.50 + 1.0 = 2.50	1.80 + 1.0 = 2.80	3.40	4.00	5.50	7.00	8.50
3.0	0.18 + 0.5 = 0.68	0.35 + 0.5 = 0.85	0.70 + 0.5 = 1.20	0.88 + 0.5 = 1.38	1.05 + 1.0 = 2.05	1.40 + 1.0 = 2.40	1.75 + 1.0 = 2.75	3.10	3.80	4.50	6.25	8.00	9.75
3.5	0.20 + 0.5 = 0.70	0.40 + 0.5 = 0.90	0.80 + 0.5 = 1.30	1.00 + 0.5 = 1.50	1.20 + 1.0 = 2.20	1.60 + 1.0 = 2.60	3.00	3.40	4.20	5.00	7.00	9.00	11.00
4.0	0.23 + 0.5 = 0.73	0.45 + 0.5 = 0.95	0.90 + 0.5 = 1.40	1.13 + 0.5 = 1.63	1.35 + 1.0 = 2.35	1.80 + 1.0 = 2.80	3.25	3.70	4.60	5.50	7.75	10.00	12.25
4.5	0.25 + 0.5 = 0.75	0.50 + 0.5 = 1.00	1.00 + 0.5 = 1.50	1.25 + 0.5 = 1.75	1.50 + 1.0 = 2.50	2.00 + 1.0 = 3.00	3.50	4.00	5.00	6.00	8.50	11.00	13.50
5.0	0.28 + 0.5 = 0.78	0.60 + 0.5 = 1.10	1.10 + 0.5 = 1.60	1.38 + 0.5 = 1.88	1.65 + 1.0 = 2.65	3.20	3.75	4.30	5.40	6.50	9.25	12.00	14.75
Flood Hazard Rating (HR)		Colour Code		Hazard to People Classification									
Less than 0.75				Very low hazard - Caution									
0.75 to 1.25				Danger for some – includes children, the elderly and the infirm									
1.25 to 2.0				Danger for most – includes the general public									
More than 2.0				Danger for all – includes the emergency services									

Flood Risk Assessment Guidance for New Development

Phase 2

Framework and Guidance for Assessing and Managing
Flood Risk for New Development –
Full Documentation and Tools

R&D Technical Report FD2320/TR2



13.S3.3 SAFE ACCESS AND EXIT

This guidance note:

- Presents simple methods for assessing the conditions that constitute safe access and exit that can be applied at the **site-specific** scale, i.e. as part of a FRA.
- Provides the Environment Agency (EA) with a means of communicating to Local Planning Authorities (LPAs) and Developers the likely flood risk to people associated with access and exit from the site.
- Is designed to be complementary to a separate EA guidance document¹⁶¹ that provides specific guidance to EA staff regarding the EA's policies and principles.

This guidance note does NOT:

- Set parameters that dictate whether or not development should be permitted, as this is dependent on the acceptability of the residual risk after provision of suitable mitigation measures and a decision for the LPA.
- Set parameters that dictate whether the EA should object to a development on the grounds of safe access and exit, as this is a policy issue for the EA.

13.1 Contents

Introduction
Requirements for Safe Access and Exit
Approach
Data and Information
Roles and Responsibilities
Processes and Procedures
Tools and Technologies
Audit and Control

13.2 Introduction

New developments are required to provide safe access and exit during a flood and the measures by which this will be achieved should be clear in the Flood Risk Assessment (FRA). Safe access and exit is required to enable the evacuation of people from the development, provide the emergency services with access to the development during a flood and enable flood defence authorities to carry out any necessary duties during the period of flood.

A safe access or exit route is a route that is safe for use by occupiers without the intervention of the emergency services or others.

Safe routes should be identified both inside and beyond the boundary of the new development. Even where a new development is above the floodplain and considered acceptable with regard to its impact on flood flows and flood storage, it should be demonstrated that the routes to and from the development are also safe to use.

A route can only be completely safe in flood risk terms if it is dry at all times.

¹⁶¹ 114_04 Safe Access and Exit From New Development During Flood Conditions

13.3 Requirements for Safe Access and Exit

The requirements for safe access and exit from new developments in flood risk areas are as follows, in decreasing order of preference:

- Safe dry route for people and vehicles
- Safe dry route for people
- If a dry route for people is not possible, a route for people where the flood hazard (in terms of depth and velocity of flooding) is low and should not cause a risk to people.
- If a dry route for vehicles is not possible, a route for vehicles where the flood hazard (in terms of depth and velocity of flooding) is low to permit access for emergency vehicles. However the public should not drive vehicles in floodwater.

Where a dry route is not possible and a route with low flood hazard is identified, the route should not have any service covers that could be removed, or other underwater hazards. It is often difficult to see underwater hazards even in shallow water, particularly at night or if the water is silty. In addition, the route should be clearly marked, for example using painted posts.

13.4 Approach

For a given development, it must be decided whether safe exit and access constitutes dry access routes or depth and velocity combinations that are below appropriately precautionary thresholds.

This decision needs to be made by the LPA in consultation with the Emergency Services and will need to take into consideration the proposed use of the development, the vulnerability of the occupants and the availability of emergency services and flood forecasting.

Any raising of ground levels to ensure safe exit and access will need to be considered in the FRA to ensure that there is no obstruction to flood flow routes and that there is no loss of flood storage capacity.

Three levels of complexity in approach are recommended in this guidance note.

- **Simple Approach**, which is based on providing a dry route up to an acceptable flood level. This approach is most precautionary and generally will be most appropriate for small and relatively low risk sites.
- **Intermediate Approach**, which is intended to identify a route with acceptable flood hazard if a dry route is not possible. This approach is based on analysis of the flood hazard (a combination of depth and velocity). This approach is also precautionary and can be applied to most sites. However, costs of site design might make it worthwhile for developers to consider the detailed approach.
- **Detailed Approach**, which is based on a more rigorous analysis of the flood hazard.

Both the intermediate and detailed approaches are based on the Flood Risks to People methodology.

These three approaches should not be confused with the tiered risk assessment approach in the Framework for Assessing and Managing Flood Risk for New Development.¹⁶² The level of assessment being undertaken (whether level 1, 2 or 3) does not preclude the use of any of the approaches described above. The selection of approach will depend on the scale of the risk and the degree of precaution that

¹⁶² See Activity Chart Process 2a – Tiered Risk Assessment

will be applied to the management of that risk. However, it is not unreasonable to envisage that more often than not, the complexity of the approach will increase if a level 2 or level 3 assessment is required.

The approach described in this guidance note concentrates on pedestrian access, as vehicles have not been considered in the Flood Risks to People methodology. However, a limited review was undertaken as part of the Defra/EA R&D project FD2321 *Flood Risk to People Phase 2* looking at safe flood depths for vehicles. In summary, this review concluded the following:

Vehicles should not be used when:

- The presence of water stops the engine functioning;
- The vehicle floats; or
- The vehicle becomes difficult to control.

Cars will stop and/or float in water as shallow as 0.5m, whilst some emergency vehicles may survive in water of 1m. A fire engine remains controllable in depths of 0.5m up to a flow velocity of 5 m/sec, due to high-level air intakes/exhausts.

13.5 Data and Information

The data and information required to assess safe access and exit depends on the complexity of the approach undertaken, as follows:

Simple Approach

- Flood levels for suitable annual probabilities (advisable to look at the 1% and 0.1% annual probabilities for fluvial flooding or the 0.5% and 0.1% for tidal/coastal flooding).¹⁶³
- Minimum ground levels along access and exit routes.

Intermediate Approach

- Flood depths and velocities for suitable annual probabilities across the development site and surrounding the development site, determined from hydraulic modelling.
- Simple lookup table relating depth and velocity to danger to people (provided in this guidance note).

Detailed Approach

- Flood depths and velocities across the development site and surrounding the development site, determined from hydraulic modelling.
- An appropriate means for determining the hazard factor for the site should be determined from the Flood Risks to People report.¹⁶⁴

13.6 Roles and Responsibilities

- The Emergency Services are the competent authorities for providing advice on entering and evacuation through floodwater and it may be necessary for them to have an input to the FRA.
- The Developer must ensure that safe access and exit are considered in the FRA.

¹⁶³ This information should be available from the EA. Alternatively, guidance of how to obtain flood levels, etc. can be found in the section called Tools and Technologies in this guidance note.

¹⁶⁴ HR Wallingford *et al.* (unpublished) *Flood Risks to People Phase 2: The Risks to People Methodology*, Defra/EA R&D Project Technical Report FD2321/TR1, due March 2005.

- The role of the Environment Agency is to support planning for safe access and exit from new developments and to object to proposals that omit suitable access and exit measures.
- The LPA in consultation with the Emergency Planning team within the local authority and the Emergency Services must decide whether safe exit and access is provided.

13.7 Processes and Procedures

13.7.1 Simple Approach

In the absence of hydraulic modelling to provide depths and velocities, the precautionary position would be to demonstrate that a development site has access and exit routes that are above flood levels for acceptable annual probability events.¹⁶⁵

If the development is behind defences, this would be the water level at the defence. Whilst this may be conservative, prediction of the actual flood level behind defences requires hydraulic modelling. If it would be impractical to design such routes, then it is necessary to undertake hydraulic modelling or obtain the results from an existing assessment (possibly available from a SFRA for the area) and then undertake either the intermediate approach or detailed approach described below.

13.7.2 Intermediate Approach

Danger to people is assessed using flood hazard, which can be expressed as a combination of flood **depth** and **velocity**. Hydraulic modelling or the use of results from an existing assessment are needed to predict flood depth and velocity.

The Flood Risks to People project has developed the following equation to relate the flood hazard to flood depth and velocity:

$$\text{Flood Hazard Rating} = ((v + 0.5) * D) + DF$$

Where:

v = velocity (m/s)

D = depth (m)

DF = debris factor

For this intermediate approach a precautionary approach has been adopted and a debris factor of 0.5 has been used for depths below and equal to 0.25 m and a debris factor of 1.0 has been used for depths above 0.25 m. These are conservative estimates based on an urban environment, as defined in the Flood Risks to People project. Based on this, the hazard rating equation has been applied to various combinations of flood depth and velocity to produce a matrix of hazard ratings. Applying thresholds to these hazard ratings defines the danger to people at various depths and velocities as shown in Table 13.1.

Therefore, if depths and velocities have been determined for the site, then this table can be used to estimate the danger to people.

¹⁶⁵ This would be agreed with the LPA, based on advice from the EA.

Table 13.1 Danger to people for different combinations of depth and velocity

Velocity (m/s)	Depth of flooding (m)											
	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	2.50
0.00												
0.10												
0.25												
0.50												
1.00												
1.50												
2.00												
2.50												
3.00												
3.50												
4.00												
4.50												
5.00												

Key:

Danger for some

Danger for most

Danger for all

For details regarding the danger classifications of ‘danger to all’, ‘danger to most’ and ‘danger to some’ reference should be made to HR Wallingford (2005) *Flood Risks to People Phase 2, The Flood Risk to People Methodology*, Environment Agency\Defra R&D Technical Report FD2321/TR1, March 2005. However, the following provides a very simplified guide as to the groups of people that should be considered as falling into these danger classifications:

- Danger for some – includes children, the elderly and the infirm.
- Danger for most – includes the general public
- Danger for all – includes emergency services

The outputs of the Flood Risk to People project indicate that flood depths below 0.25 m and velocities below 0.5 m/s are generally considered low hazard. When designing safe access and exit routes, the combinations of depth and velocity on the routes should correspond to the white boxes in the above diagram. As flood depth and/or velocity increase the hazard to people increases. Combinations of depths and velocities in the white boxes (below the ‘danger for some’ class) are ‘very low hazard’, but a hazard does remain.

Depending on circumstances, alternative debris factors can be used based on the recommendations from the Flood Risks to People project.

13.7.3 Detailed Approach

Table 13.1 is a simple translation of a depth and velocity combination at selected points in the development site into a danger to people category. For large, complex developments this could be a time consuming exercise and difficult to test multiple options. Therefore, a more detailed approach would be to undertake flood hazard mapping across the area being considered based on the results of hydraulic modelling.

The advantage of this approach is that the mapping can also usefully inform the flood warning and emergency planning for the site.

13.8 Tools and Technologies

13.8.1 Determining Flood Hazard

It is possible to use either the lookup table provided in this guidance note or refer to the Flood Risks to People project, which provides a discussion of alternative methods for calculating flood hazard and suitable variations in debris factor depending on the characteristics of the site.

13.8.2 Hydraulic Modelling

There are a range of hydraulic modelling methods that can be used to estimate flood depths and velocities. Methods are summarised below (in the order of least complex to most complex):

- **Existing flood maps and topographic data.** Existing maps can be used to estimate flood depth but do not provide any information on velocities. For some simple applications of the method it may be appropriate to estimate peak velocities based on normal depth calculations or even expert judgement. Any assumptions made should be conservative (assuming high velocities).
- **Conveyance calculation.** The new Conveyance Estimation System (CES) can be used to estimate velocities across a floodplain for river valleys without defences.¹⁶⁶
- **One-dimensional hydraulic models** with defined flood storage areas and active floodplain channels, e.g. ISIS Flow or MIKE11 software, can be used to estimate average velocities. Maximum velocities can be significantly higher in some parts of the floodplain, e.g. where water spills over a defence, in narrow streets and any other “pinch points” in the floodplain.
- **Flow routing using a “raster” GIS system**, e.g. the JFLOW model used for the fluvial component of the EA’s Extreme Flood Outline project.
- **Two-dimensional hydraulic modelling using a fixed grid**, e.g. the TUFLOW hydraulic model that has been used for modelling the floodplain of the tidal Thames or HYDRO F that was used for the tidal component of the EA’s Extreme Flood Outline project.
- **Two-dimensional hydraulic modelling using a triangular mesh**, e.g. the Telemac 2D model. This can provide good velocity estimates but model run times are significantly longer than grid based models.

Outputs from the raster and two-dimensional models can be converted directly to flood hazard as they provide depth and velocity at regular intervals across the flood hazard areas.

Flood velocities produced by one and two-dimensional models will be average velocities for a cross-section or grid cell. There will be considerable variation of flow velocities within a river cross-section and for all modelling approaches peak flow velocities may be much higher than the average velocities reported for a cross-section or grid-cell. This is particularly the case in urban areas where flows may be concentrated in narrow streets and between buildings.

13.9 Audit and Control

When checking the analysis of depths and velocities, due consideration needs to be given to the accuracy of the model predictions, which will depend on the type of model used, as listed in Tools and Technologies.

¹⁶⁶ See <http://www.river-conveyance.net>

Appendix A.8 – Risk of flooding from surface water extent for Framfield Road



Flood risk summary for the area around:

185, FRAMFIELD ROAD, UCKFIELD, TN22 5AU

Surface water

High risk

► [More information about your level of flood risk from surface water](#)

Surface water flooding happens when rainwater cannot drain away through the normal drainage systems. Instead, it lies on or flows over the ground. Surface water flooding is sometimes known as flash flooding. It can:

- be difficult to predict as it depends on rainfall volume and location
- happen up hills and away from rivers and other bodies of water
- affect areas with harder surfaces, like concrete, more severely

Lead local flood authorities (LLFA) are responsible for managing the flood risk from surface water and may hold more detailed information.

Your LLFA is **East Sussex council**.

Appendix A.9 – Phase I Desk Study and Site Reconnaissance Report (2015)

Phase I Desk Study and Site Reconnaissance Report

at Bird in Eye Farm,
Uckfield

for Croudace Homes Ltd

Report Reference : LP00936

Report Date : 29th April 2015

Leap Environmental Ltd

The Atrium, Curtis Road,
Dorking, Surrey, RH4 1XA

tel +44 (0) 1580 211605

fax +44 (0) 1306 646511

www.leapenvironmental.com

South Coast Regional Office Premier House, Victoria Road, Burgess Hill, West Sussex RH15 9LR

Kent Regional Office Spelmonden Old Oast, Spelmonden Farm, Goudhurst, Kent, TN17 1HE



B PHASE I – DESK STUDY

5 Environmental Setting

5.1 Site Location and Description

The site is located at Bird in Eye Farm, to the south of Bird in Eye Hill, to the south east of Uckfield town centre.

The approximate National Grid Reference of the site is 548320 120690. The site lies at an estimated elevation of 35m Above Ordnance Datum (mAOD).

5.1.1 General Description and Boundaries

The current site layout is shown in Figure 1, Appendix B. A walkover survey was carried out on 21st April 2015 and photographs are included within Appendix C.

The site, which extends to approximately 9.5Ha comprised fields divided into horse paddocks sloping down moderately steeply to the south west towards a stream. There was some evidence noted during the walkover of shallow soil movement adjacent to the stream.

The site is bound by Bird in Eye Hill Road to the north, Nightingale Wood to the south, Framfield Stream to the west and farm buildings and fields to the east.

5.2 Geology

The geology of the site has been ascertained by reference to the 1:50,000 British Geological Survey sheet 319/334, Lewes and Eastbourne, and the Envirocheck report. The site is mapped as being underlain by the Lower Tunbridge Wells Sand. There are no superficial deposits mapped overlying the Lower Tunbridge Wells Sand.

5.2.1 Lower Tunbridge Wells Sand

The Lower Tunbridge Wells comprises a lower unit of thinly interbedded silty fine-grained sandstones and siltstone with occasional beds of clay or silty clay, and an upper unit of thickly bedded, fine and medium-grained sandstone (the Ardingly Sandstone Member of the Tunbridge Wells Sand Formation).

5.2.2 British Geological Survey Boreholes

The online British Geological Survey Borehole Map viewer (<http://mapapps.bgs.ac.uk/geologyofbritain/home.html?mode=boreholes>) has been reviewed for more detailed local geological and hydrogeological information. Two boreholes have been identified within 500m of the site. Borehole ref 632724, is located within the site boundary in the north east corner of the site. This borehole indicates ground conditions comprise medium dense to dense light grey and brown silty occasionally clayey silty sand with thin layers of very weak fine grained sandstone over very weak to weak light grey and orange brown sandstone.

Borehole ref 632730, located 300m west of the site, shows groundwater was encountered at 14m AOD which is approximately 7-8m below ground.

5.3 Hydrogeology

The hydrogeology of the site has been ascertained from the Envirocheck data report. The source of the data is reported to be the Environment Agency groundwater vulnerability mapping.

The Lower Tunbridge Wells Sand deposits which are mapped beneath the site are classified as a Secondary A aquifer.

The site is not situated a Groundwater Source Protection Zone (SPZ).

The Envirocheck report lists two active abstraction licences within 1000m of the subject site. These are located 842m to the north west of the site and are licensed for public water supply.

5.4 Hydrology

The Framfield Stream runs along the southern and western boundaries of the site and is shown on the Envirocheck map to run towards the north. The Environment Agency have surface water quality data for the Framfield Stream and this is reported as good.

The Envirocheck report indicates that there are five discharge consents within 250m of the site, the nearest is 150m west of the site and is for the discharge of surface water into the Framfield Stream.

5.5 Flooding

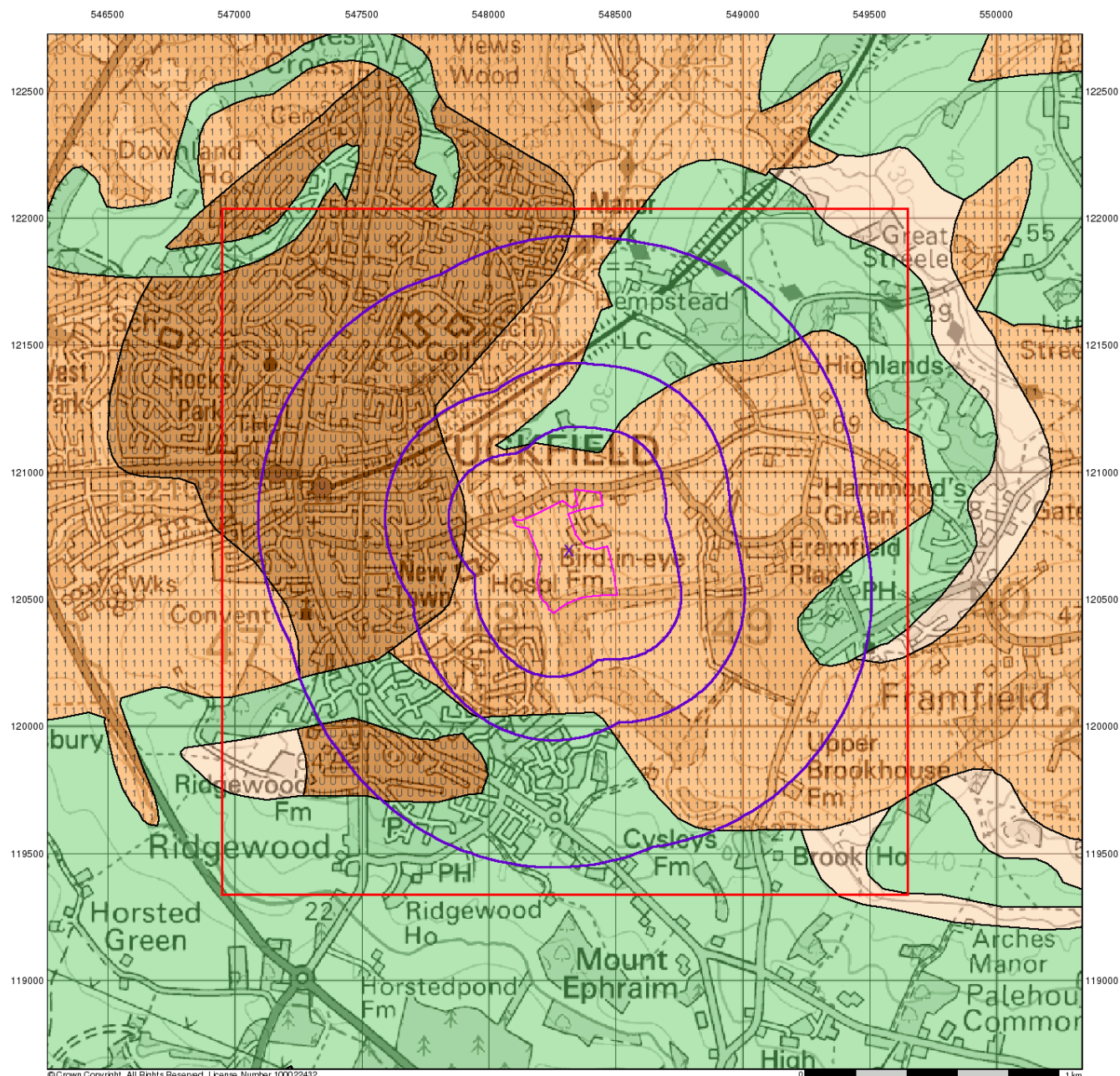
According to the Environment Agency, the southern and western boundaries of the site are designated to be in a zone 2 floodplain.

A zone 2 floodplain estimates the annual probability of flooding as one in one thousand (0.1%) or greater from rivers and the sea but less than 1% from rivers or 0.5% from the sea.

5.6 Designated Environmentally Sensitive Sites

A review of designated environmentally sensitive sites presented within the Envirocheck report has been carried out. The dataset makes reference to a number of sensitive sites including the following:

- Sites of Special Scientific Interest (SSSI);
- Records of National Nature Reserves (NNR);
- Areas of Special Conservation (SAC);
- Records of Special Protection Areas (SPA);
- Records of Ramsar Sites;



Groundwater Vulnerability

General

- Specified Site
- Specified Buffer(s)
- Bearing Reference Point
- Slice
- Map ID

Agency and Hydrological

Geological Classes

Major Aquifer (Highly Permeable)

Minor Aquifer (Variably Permeable)

Non Aquifer (Negligibly Permeable)

Water or Sea

Drift Deposit

Soil Classes

High (H) 1, 2, 3, U

Intermediate (I) 1, 2

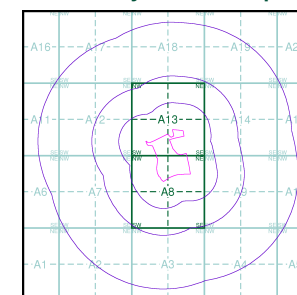
Low

High (H) 1, 2, 3, U

Intermediate (I) 1, 2

Low

Site Sensitivity Context Map - Slice A



Order Details

Order Number: 66527266_1_1
 Customer Ref: LP936
 National Grid Reference: 548320, 120690
 Slice: A
 Site Area (Ha): 9.72
 Search Buffer (m): 1000

Site Details

Bird in Eye Farm, Bird in Eye Hill, Framfield, UCKFIELD, East Sussex, TN22 5HA



Tel: 0844 844 9952
 Fax: 0844 844 9951
 Web: www.envirocheck.co.uk

Appendix A.10 – Extracts from relevant guidance

BS8582:2013

Guide to Sustainable Drainage Systems in East Sussex (June 2015)

Sustainable Drainage Systems – Non-statutory technical standards for sustainable drainage systems (March 2015)

Ciria C753 The SuDS Manual

Susdrain – Assessing attenuation storage volumes for SuDS

BS 8582:2013



BSI Standards Publication

Code of practice for surface water management for development sites

bsi.

...making excellence a habit.™

NOTE 1 In Scotland, WAT-RM-08 [8] (section 7.8) does not require a groundwater sensitivity assessment for low hazard run-off sources (e.g. roof water, car park run-off).

NOTE 2 This can be done through reference to the groundwater designation mapping for England and Wales [available on the Environment Agency website ³⁾], the SEPA groundwater vulnerability map [available on the SEPA website ⁴⁾]. The aquifer designation dataset is available on request from the British Geological Survey. In Northern Ireland aquifer classification is based on potential productivity (high, moderate, limited and poor) and regional information on aquifer vulnerability class which can be obtained from the Geoindex on the BGS/Geological survey of Northern Ireland websites ⁵⁾.

NOTE 3 The level of groundwater sensitivity reflects the importance of the underlying aquifer as a resource (drinking water supply) but also any role it might have in supporting environmentally sensitive surface water bodies.

7.7.2 Surface water sensitivity

To determine the sensitivity of any receiving surface water body to the discharge of potentially contaminated surface run-off from a development site, the following designations should be checked:

- a) the ecological status of the water body and its established future ecological potential (Water Framework Directive [15] status and environmental designations);
- b) whether the water body is designated for the abstraction of water for human consumption; and
- c) whether the water body is designated for recreational use.

NOTE Where the drainage system discharges to a public surface water sewer or highway drainage system, then this is considered as a conduit/pathway to the receiving surface water body.

8 Evaluating the proposed development site characteristics relating to surface water run-off

8.1 General

The development site characteristics that specifically influence the rate, volume and likely contamination levels of the surface water run-off should be determined in accordance with 8.2 to 8.5.

8.2 Size and sub-catchment delineation of the drainage area

The development drainage area should be established and delineated into sub-catchments or drainage zones to reflect the proposed development layout, likely run-off conveyance routes and storage zones, and land use.

8.3 Development density and percentage impermeability (including urban creep allowances)

For each of the proposed sub-catchments/drainage zones, the percentage impermeability of the contributing run-off areas should be evaluated to determine the proportion of rainfall that is discharged into the surface water management system during rainfall events.

³⁾ See <http://www.environment-agency.gov.uk> [last viewed 27 July 2013].

⁴⁾ See <http://www.sepa.org.uk/> [last viewed 27 July 2013].

⁵⁾ See <http://www.bgs.ac.uk/geoindex/> and <http://www.bgs.ac.uk/gsni/data/> [last viewed 27 July 2013].

For green space and gardens, the likely run-off contributions of these areas to the drainage systems should be estimated.

To allow for future urban expansion within the development (urban creep), an increase in paved surface area of 10% should be used, unless this would produce a percentage impermeability greater than 100%, or unless specified differently by the drainage approval body or planning authority.

8.4 Rainfall characteristics (including climate change allowances)

Rainfall depths for all relevant return periods and for a range of durations should be determined for the site using the FEH rainfall depth-duration-frequency (DDF) model [30]. Where FEH rainfall information is not available, the Flood Studies Report [37] rainfall depths can be used; FSR:FEH rainfall maps in W5-074, Appendix A [38] should be used to provide suitable uplifts to the FSR rainfall for the relevant location.

Uplifts on rainfall intensities that take account of future climate change should be applied (see Table B.1), unless alternative approaches to increasing the resilience of systems to climate change risks (adaptability) are specified by the drainage approval bodies. All approaches should be confirmed as being applicable for development with the planning and/or drainage approval authority.

8.5 Land use

The type of development proposed within each of the sub-catchments should be mapped and characterized to define the potential contamination hazard posed by the run-off from each area.

The pollution hazard assessment should be evaluated in conjunction with the sensitivity of the receiving water body (see 7.7) to determine the level of treatment required for the surface water run-off.

NOTE 1 In Scotland the number of properties or car park spaces drained to the drainage system has an influence on the level of assumed hazard posed: WAT-RM-08 [8] gives guidance on how to characterize the system.

NOTE 2 Guidance on when discharges are classified as trade effluent and environmental permitting for point source discharges to surface water or groundwater can be sourced from the relevant environment regulator.

9 Drainage design methods and tools

9.1 Development site run-off simulation

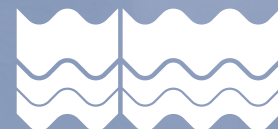
The performance of the proposed drainage system for the site should be analysed (using appropriate tools and/or models) to show conformity of the system with the surface water management criteria for the site.

The analysis should take into account the different critical durations of storms relevant to each of the drainage elements when determining maximum water levels, storage volumes and flow rates through the system.

9.2 Rainwater harvesting and use design

NOTE 1 The capture and use of stormwater presents an opportunity to conserve water resources.

NOTE 2 Where infiltration is not possible and evapotranspiration is low, rainwater harvesting is the only way to reduce the volume of runoff (5.2.2.4)



Guide to Sustainable Drainage Systems in East Sussex



What is required in East Sussex

Revisions to the SuDS Manual, available on the susdrain website, have a series of priority checklists and frameworks on the planning, design, construction and maintenance of SuDS. It is strongly recommended that these checklists and frameworks are consulted and completed during outline planning, especially the following:

- SuDS planning and design process (RP992/15)
- Health and safety principles (RP992/17)
- Scheme design assessment (RP992/18)
- Infiltration assessment (RP992/19)

Table 3F.1 opposite sets out the information recommended for submission to the local planning authority as part of an outline planning application. A Design Code for the whole site would be required on multi-phased developments to make sure the concepts of the drainage strategy are carried forward to plot level design.

Balancing pond at Grovelands Farm, Hailsham, East Sussex

(Source: Revai Kinsella, East Sussex County Council)

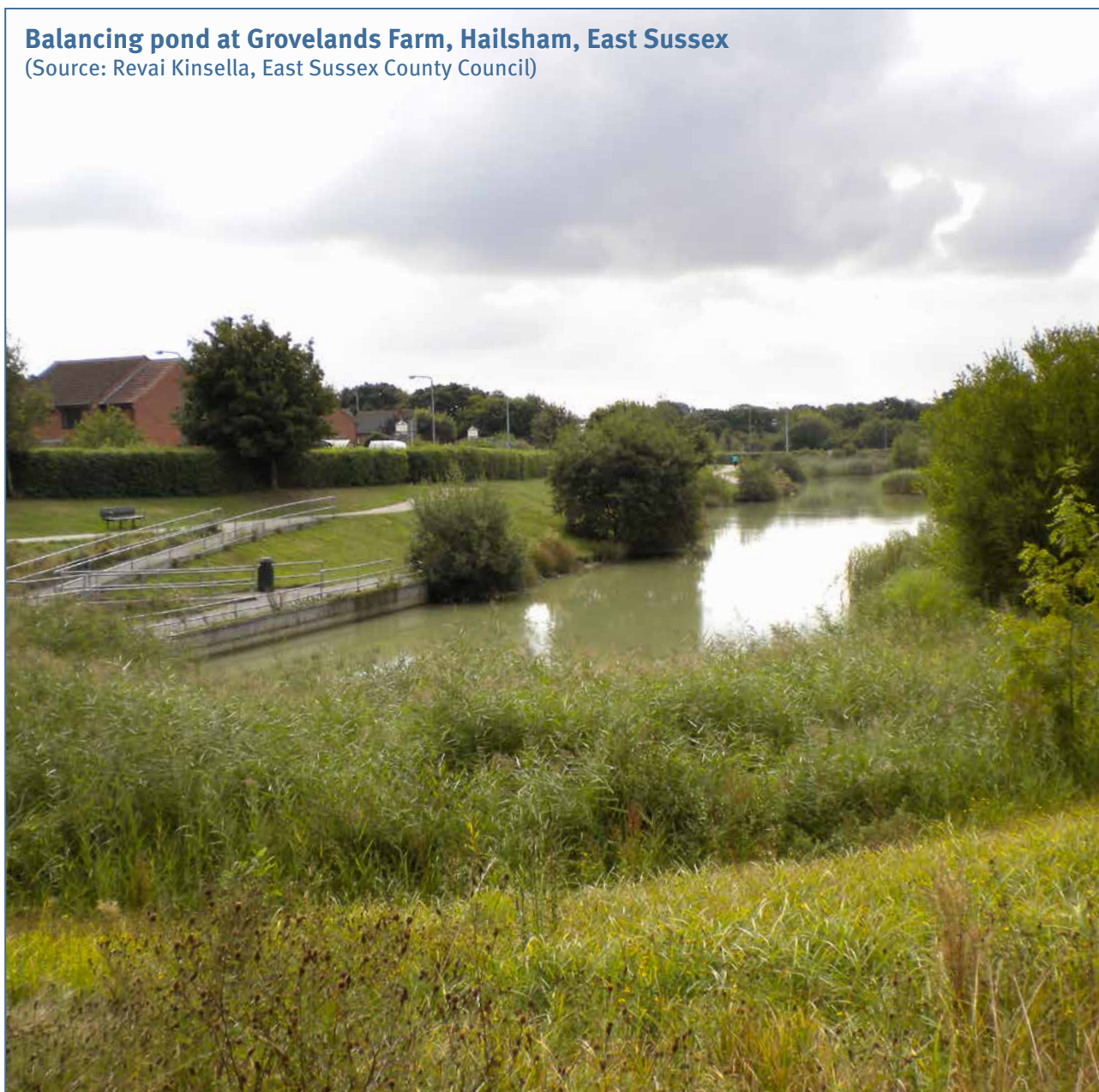


Table 3F.1: Outline design checklist

Item	Description	Format
Existing drainage	Details of existing drainage arrangements on site, including catchment areas, contours (or site levels) and any drainage systems to which the site drains.	Drawing (s) – full size paper copy or pdf
Drainage layout plan	A site plan showing the location of SuDS features, conveyance paths, discharge points, storage and treatment areas.	Drawing(s)
SuDS/Drainage strategy	Evidence demonstrating compliance with Planning Practice Guide on SuDS and the non-statutory technical standards such as runoff destination hierarchy, maintenance and management of runoff on the surface wherever possible.	Drawing(s), report or statement
Site investigations	Site investigations such as topographic survey and ground investigations, including groundwater monitoring. Infiltration (soakage) tests at the location of each proposed infiltration SuDS feature. Soakage tests should be in accordance with BRE365.	Drawing(s), test results and interpretive report
SuDS benefits	Demonstrate how the SuDS benefits described in Section 1 of this report and ‘Water. People. Places’ have been incorporated into the design, to create multi-functional SuDS features, including how biodiversity can be compensated and/or enhanced.	report or statement
Discharge and volumes	Calculations showing the pre-development runoff rates and volumes, and post-development runoff rates together with the size drainage structures.	Calculations
Climate change and urban creep	Demonstrate consideration of likely impacts of climate change and likely changes in impermeable area within the development over its lifetime ¹ .	Calculations and statement
Landscape	Demonstrate how SuDS have been designed to integrate with the beautiful landscape of East Sussex and to link with green infrastructure.	Drawing(s), report, statement
Conveyance routes	Show how runoff would be conveyed between different SuDS features safely.	Drawing(s), report, statement
Excess flows	Show how flows in excess of the design event will be managed safely, including the relevant calculations.	Drawing(s), report, statement
Stakeholder consultation	Records of correspondence with the relevant stakeholders and regulatory authorities to demonstrate approval has been agreed in principal.	Letters, emails, telephone records
Offsite impacts	An assessment of offsite impacts, demonstrating how they have been managed.	Report, statement
Drainage design code (for multi-phased developments only)	Details of how the principles of the drainage strategy for the whole site will be retained for each phase or plot.	Report or statement

¹ BS 8582:2013 recommends a 10% increase in impermeable area to take into account urban creep.

Sustainable Drainage Systems

Non-statutory technical standards for sustainable drainage systems

March 2015

Contents

Introduction	1
Flood risk outside the development	1
Peak flow control	1
Volume control	1
Flood risk within the development.....	2
Structural integrity	2
Designing for maintenance considerations	2
Construction.....	2

Introduction

This document sets out non-statutory technical standards for sustainable drainage systems. They should be used in conjunction with the [National Planning Policy Framework](#) and [Planning Practice Guidance](#).

Flood risk outside the development

S1 Where the drainage system discharges to a surface water body that can accommodate uncontrolled surface water discharges without any impact on flood risk from that surface water body (e.g. the sea or a large estuary) the peak flow control standards (**S2** and **S3** below) and volume control technical standards (**S4** and **S6** below) need not apply.

Peak flow control

S2 For greenfield developments, the peak runoff rate from the development to any highway drain, sewer or surface water body for the 1 in 1 year rainfall event and the 1 in 100 year rainfall event should never exceed the peak greenfield runoff rate for the same event.

S3 For developments which were previously developed, the peak runoff rate from the development to any drain, sewer or surface water body for the 1 in 1 year rainfall event and the 1 in 100 year rainfall event must be as close as reasonably practicable to the greenfield runoff rate from the development for the same rainfall event, but should never exceed the rate of discharge from the development prior to redevelopment for that event.

Volume control

S4 Where reasonably practicable, for greenfield development, the runoff volume from the development to any highway drain, sewer or surface water body in the 1 in 100 year, 6 hour rainfall event should never exceed the greenfield runoff volume for the same event.

S5 Where reasonably practicable, for developments which have been previously developed, the runoff volume from the development to any highway drain, sewer or surface water body in the 1 in 100 year, 6 hour rainfall event must be constrained to a value as close as is reasonably practicable to the greenfield runoff volume for the same event, but should never exceed the runoff volume from the development site prior to redevelopment for that event.

S6 Where it is not reasonably practicable to constrain the volume of runoff to any drain, sewer or surface water body in accordance with **S4** or **S5** above, the runoff volume must be discharged at a rate that does not adversely affect flood risk.

Flood risk within the development

S7 The drainage system must be designed so that, unless an area is designated to hold and/or convey water as part of the design, flooding does not occur on any part of the site for a 1 in 30 year rainfall event.

S8 The drainage system must be designed so that, unless an area is designated to hold and/or convey water as part of the design, flooding does not occur during a 1 in 100 year rainfall event in any part of: a building (including a basement); or in any utility plant susceptible to water (e.g. pumping station or electricity substation) within the development.

S9 The design of the site must ensure that, so far as is reasonably practicable, flows resulting from rainfall in excess of a 1 in 100 year rainfall event are managed in exceedance routes that minimise the risks to people and property.

Structural integrity

S10 Components must be designed to ensure structural integrity of the drainage system and any adjacent structures or infrastructure under anticipated loading conditions over the design life of the development taking into account the requirement for reasonable levels of maintenance.

S11 The materials, including products, components, fittings or naturally occurring materials, which are specified by the designer must be of a suitable nature and quality for their intended use.

Designing for maintenance considerations

S12 Pumping should only be used to facilitate drainage for those parts of the site where it is not reasonably practicable to drain water by gravity.

Construction

S13 The mode of construction of any communication with an existing sewer or drainage system must be such that the making of the communication would not be prejudicial to the structural integrity and functionality of the sewerage or drainage system.

S14 Damage to the drainage system resulting from associated construction activities must be minimised and must be rectified before the drainage system is considered to be completed.



© Crown copyright 2015

You may re-use this information (excluding logos) free of charge in any format or medium, under the terms of the Open Government Licence v.3. To view this licence visit www.nationalarchives.gov.uk/doc/open-government-licence/version/3/ or email PSI@nationalarchives.gsi.gov.uk

This publication is available at www.gov.uk/government/publications

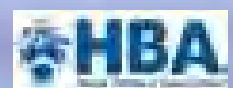
Any enquiries regarding this publication should be sent to us at suds@defra.gsi.gov.uk

PB14308



NON-STATUTORY TECHNICAL STANDARDS FOR SUSTAINABLE DRAINAGE

Practice Guidance



Appendix B:

Definitions

For the purposes of these standards and this document the following definitions apply.

“1 in 1 year rainfall event” means an event that has a probability of occurring, on average, once a year. The depth of rainfall for the event will depend on the duration of event being considered.

“1 in 30 year rainfall event” means an event that has a probability of occurring, on average, of 3.3% in any one year. The depth of rainfall for the event will depend on the duration of event being considered.

“1 in 100 year rainfall event” means an event that has a probability of occurring, on average, of 1% in any one year. The depth of rainfall for the event will depend on the duration of event being considered.

“Climate change allowances” These are appropriate allowances for the predicted changes in Sea Level, Rainfall, peak River flow etc. as a result of climate change – see information provided by the Environment Agency on the GOV.UK web site

“Communication” method by which the approved drainage system connects to a public sewer, drainage system or water body

“Completed” drainage system is considered to be complete when the works have been constructed fully in accordance with the approved design

“Curtilage” the area of land around a building or group of buildings which is for the private use of the occupants of the buildings.

“Damage” damage within the context of construction includes any impact on functionality e.g. silt deposits, broken pipes, ruts, loss or lack of vegetation, damage to topsoil caused by stockpiling too high

“Design life of the development” Dependent on nature of site and development. Typically 60 years for commercial development.

“Drainage strategy” A document containing the full design, construction, operation and maintenance details of a drainage system to manage surface water. This document will form part of the drainage application which is submitted to the local planning authority for determination.

“Drainage system” all the components that convey the surface to a point of discharge.

“Exceedance” an event that exceeds the capabilities of the surface water drainage system could be excessive rainfall, or blockage or combination of tidal and pluvial events

“Greenfield runoff rate” The rate of runoff that would occur from the site in its undeveloped and therefore undisturbed state.

“Impermeable area” all paved or roof areas that are not specifically designed to be permeable.

“Maintenance” means the on-going maintenance of all elements of the sustainable drainage system (including mechanical components) and will include elements such as; on-going inspections relating to performance and asset condition assessments, operation costs, regular maintenance, remedial works and irregular maintenance caused by less sustainable limited life assets.

“Operation” Activities which are required to ensure that control components function as per the approved design

“Peak rate of runoff” is the highest rate of flow from a defined catchment area assuming that rainfall is uniformly distributed over the drainage area, considering the entire drainage area as a single unit and estimation of flow at the most downstream destination(s) only

“Previously developed land” refer to definition in Annex 2 NPPF. This may be referred to as brownfield development.

“Single property drainage system” This is the constituent parts of a drainage system within the curtilage of a single property and that only receive flows from that property.

“Structural integrity” Ensures that a system fulfils its design function

“Unacceptable deformation” Changes, failure or damage that prevents the design function of the component or drainage system such that safety and/or flood risk is adversely impacted.

“Urban Creep” This is the conversion of permeable surfaces to impermeable over time e.g. impermeable surfacing of front gardens to provide additional parking spaces, extensions to existing buildings, creation of large patio areas. The consideration of urban creep (is best) assessed on a site by site basis but is limited to residential development only.

It is important that the appropriate allowance for urban creep is included in the design of the drainage system over the lifetime of the proposed development. The allowances set out below are applied to the impermeable area within the property curtilage:

Residential development density Dwellings per hectar	Change allowance % of impermeable area
≤ 25	10
30	8
35	6
45	4
≥ 50	2
Flats & apartments	0

Note where the inclusion of the appropriate allowance would increase the total impermeable area to greater than 100%, 100% should be used as the maximum.

“Viability” as used in the explanatory notes reflects economic viability as defined within the Town and Country Planning Act and utilised by Local Planning Authorities.

“Water body” A manageable unit of surface water, being the whole (or part) of a stream, river or canal, lake or reservoir, transitional water (estuary) or stretch of coastal water. A ‘body of groundwater’ is a distinct volume of groundwater within an aquifer or aquifers.

‘Developers have a vital role to play in delivering the outcomes of risk management strategy. Planning authorities should take necessary regard of not just the statutory planning framework and the National FCERM Strategy, but also the Local Flood Risk Management Strategy. The Local Strategy should be considered as supplementary planning guidance (SPG) and therefore form a material consideration in the planning process. In so doing, future developments will take proper regard of the local flood risk management strategy including the risk of flooding from surface water, groundwater and ordinary watercourses. Information on principally coastal and fluvial flooding may be found in the Strategic Flood Risk Assessment, although some also seek to address surface water flood risk’.

The SuDS Manual



Department
for Environment
Food & Rural Affairs



Flood and Coastal Erosion Risk Management R&D

SuDS components are inherently more adaptable than fixed capacity, subsurface drainage infrastructure. In some cases where future ownership and investment capacity are assured, drainage systems might be designed with the flexibility for increasing capacity later in their design life, when climate change risks can be better quantified or when a higher level of service is required.

Otherwise, up-to-date rainfall intensity uplift factors for individual regions for climate change scenarios (Section 24.7.1) should be sourced from relevant ministerial or local government guidance, and incorporated within the design calculations to ensure the design is robust.

Increasing impermeability of the contributing catchment through the design life of the drainage system, should also be taken into account. Urban creep (ie the addition of patios, conservatories, extensions, impermeable driveways and other hardstandings) can be significant, particularly in low-to-medium-density developments, and an appropriate design factor should be agreed with the drainage approving body before drainage system design (Section 24.7.2).

3.3 WATER QUANTITY DESIGN STANDARDS

The following standards are standards of “good practice”. Local planning documents, national standards or other guidance from approving or adopting organisations may take precedence.

The research underpinning the standards on the use of peak flow rates and volume control of discharges is provided in Kellagher (2002).

BOX 3.1 Return periods, probability of occurrence and critical durations

The **return period** of a rainfall event is the average time between events of a given or greater magnitude, usually expressed in years. A 100-year return period event refers to an event that occurs or is exceeded on average once every hundred years. This can also be expressed as the 1 in 100 or 1:100 year event.

Alternatively, an event can be described as having a **probability of occurrence** (or frequency of occurrence), which is 1/return period but often expressed as a percentage. For a 1:100 year event, this would be 1%, ie there is a 1% chance of the event occurring or being exceeded in any one year.

Estimates of return periods are subject to uncertainty, so in reality, consecutive events can occur at intervals greater or smaller than their average return period. A 1:1 year event refers to an event that has a 100% chance of occurring in any one year, and thus could be interpreted as a range of events beneath a certain threshold. However, for the purpose of these standards, when referring to a 1:1 year event, this should be taken as meaning an event that occurs, on average, once a year.

The **critical duration** is the duration of rainfall event for a specified return period event (usually given in hours) that results in the greatest peak flow rate, flood volume or flood level (depending on the purpose of the analysis) at a particular location. It will be different for different locations on a site.

3.3.1 Water quantity standard 1: Control of runoff volume

The volume of runoff should be controlled for the following two scenarios:

a Volume control for frequent rainfall events

The drainage system should be designed so that runoff from the site to receiving surface waters does not occur for the majority of small rainfall events.

b Volume control for extreme rainfall events

The drainage system should be designed so that the volume of runoff discharged from the site during extreme events (normally specified as a 1:100 year event) is controlled.

Interpretation of this standard is presented as follows.

a) Volume control for frequent rainfall events

The prevention of runoff from the site for the majority of small (frequent) rainfall events (or for the initial depth of rainfall for larger events) is called **Interception**, and Interception of about 5 mm is normally achievable. From a hydraulic perspective, Interception is required to mimic greenfield hydraulic response characteristics where small rainfall events do not generally produce any runoff and thus to protect the morphology and ecology of the receiving watercourse, and the hydrological soil water balances in the catchment. Interception can be delivered using a variety of methods including rainwater harvesting, infiltration and evapotranspiration. Interception design methods are set out in [Section 24.8](#).

This standard is the same as water quality standard 1 ([Chapter 4](#)). This is because the delivery of Interception provides both water quantity and water quality benefits. Compliance with this standard is not usually achievable during periods of wet weather, so a flexible approach is required (eg a requirement to achieve Interception for a given proportion of events during the summer and a lower proportion during the winter). In winter or during extended wet periods, the risks to the ecology and morphology of the receiving watercourse from urban runoff are likely to be lower.

b) Volume control for extreme rainfall events

Because the volume of runoff from the site can be, in many scenarios, as damaging to downstream flood risk as peak flow rates ([Section 3.1](#)), it is necessary to ensure that runoff volumes discharged from the site during extreme events are also controlled.

This means that, where possible, the volume of runoff from the site (or development) area should not exceed the volume of runoff from the equivalent area in its natural undeveloped or “greenfield” state (for the same rainfall event). Methods for estimating greenfield/pre-development runoff volumes are described in [Section 24.4](#). Where flood risk from the receiving watercourse is particularly high, tighter local criteria for allowable volumes discharged from the site may need to be specified by the local regulator or drainage approving body and met by the drainage design.

The use of infiltration and rainwater harvesting are important mechanisms for delivering volume control: the greater the volume of runoff that is infiltrated or used on site, the lower the volume of runoff discharged. It is important to note that, for clay sites, greenfield runoff volumes will tend to be high because of the underlying impermeability. So the increase in volume for the developed site will be small. Where developments take place on more permeable soils, the difference will be far greater, but infiltration options should be available to assist in managing these larger volumes.

Ideally, the volumetric control of runoff should be demonstrated to meet greenfield runoff behaviour for all events and particularly those that are relevant for the mitigation of flood risk in the receiving watercourse. However, this would require the use of time series rainfall as part of a modelling exercise. Until this approach becomes standard industry practice, a simple method using the 1:100 year, 6 hour rainfall event can be sufficient for design purposes, as it represents a suitable event for protecting smaller watercourses that are most at risk from the effects of urban development. As designs for Interception will help control runoff volumes from smaller events, a single requirement for large events is considered pragmatic and not overly onerous.

Where controlling runoff to greenfield volumes is considered unachievable, then the runoff volume should be reduced as much as possible and any additional volume should be stored and released at a low rate that will not increase downstream flood risk (normally 2 l/s/ha is considered an appropriate rate (Kellagher, 2002)) using either of the following approaches*:

- 1 The additional runoff volume (ie the difference between the predicted development runoff volume and the estimated greenfield runoff volume for the 100 year event, often called **Long-Term Storage**) should be discharged from the site at a rate of 2 l/s/ha or less, while still allowing greenfield runoff peak flow rates to be applied for the greenfield runoff volume.

Note

- * The 6 hour event can be used unless more detailed local catchment modelling has been undertaken to justify an alternative duration.

- 2 All the runoff from the site for the 1:100 year event should be discharged at either a rate of 2 l/s/ha or the average annual peak flow rate (ie the mean annual flood, QBAR), whichever is the greater.

Approach 2 provides a simpler approach, but results in larger storage volumes being required than Approach 1.

The calculation of the difference in volume between the developed and greenfield scenario (defined as the Long-Term Storage Volume) is set out in [Section 24.10](#).

For previously developed sites, the surface water management system should be designed so that the volume of surface water runoff discharged from the site for the 1:100 year, 6 hour event is kept as close to greenfield conditions as possible. The runoff volume for the pre-development scenario may be very high and may be contributing to downstream flood risk – it should therefore only be allowed for the new development if the drainage approving body agrees that it is acceptable. Wherever runoff volumes cannot be sufficiently reduced, they should be discharged from the site at a rate of 2 l/s/ha or less (see above).

3.3.2 Water quantity standard 2: Control of peak rate of runoff

a Control peak runoff rates during events likely to impact on morphology, ecology or capacity of receiving surface waters, or capacity of receiving sewers

The drainage system should be designed so that peak runoff rates from the site for events likely to be significant for the morphology/ecology/capacity of receiving surface waters, or the capacity of receiving sewers (normally specified as approximately a 1:1 year event) are constrained to the greenfield rates of runoff for the same return period.

b Control peak runoff rates during extreme rainfall events

The drainage system should be designed so that the peak runoff rates for extreme rainfall events (normally specified as a 1:100 year event) are constrained to the greenfield rates of runoff for the same event.

The assessment of peak runoff rates and the design of attenuation storage systems is set out in [Sections 24.6 and 24.9](#), respectively. The critical duration rainfall event should be used in determining the maximum attenuation storage volumes. Different critical durations will apply to different storage and conveyance elements used on the site.

Interpretation of this standard is presented as follows.

a) Control peak runoff rates during events likely to impact on morphology, ecology or capacity of the receiving surface waters, or the capacity of receiving sewers

A bankfull event for a stream or river tends to equate to about a 1:1 or 1:2 year event. By aiming to replicate greenfield runoff rates for this size of event, the receiving watercourse can be protected from erosion and the resulting morphological and ecological damage. For previously developed sites, site runoff rates should be reduced to the greenfield rates wherever possible.

By limiting discharges to sewers (and surface waters), this will reduce the impact on downstream capacity. If discharging to a combined sewer, this also reduces the impact on CSO spills and downstream wastewater treatment works.

For soils with relatively high permeabilities, the 1:1 year greenfield runoff rate may be considered too low to be feasible. In this case, a minimum throttle rate should be agreed by the drainage approving body. An appropriate limit is likely to be 1–2 l/s/ha. Guidance on controlling low flows is provided in [Chapter 28](#).

b) Control peak runoff rates for extreme events to prevent surface water runoff from the site increasing downstream flood risk

Aiming to replicate greenfield runoff rates for extreme events helps ensure that the flood risk associated with the receiving watercourse/sewer is not increased by the development. Volume control (as required by water quantity standard 1) is also an important part of the flood risk mitigation approach.

Chapter 24

Hydrology and hydraulics: design methods and calculations

This chapter presents the design methods and tools required to size storage and conveyance systems to meet the water quantity design criteria and good practice design standards. This includes how to estimate runoff for the greenfield or previously developed site.

- ▶ Water quantity design criteria are set out in Chapter 3.
- ▶ Guidance on the SuDS design process is provided in Chapter 7, with an overview of the process for sizing storage and conveyance system components presented in Figure 7.12.
- ▶ Guidance on component sizing for water quantity and water quality management is provided in Chapters 11–23.
- ▶ Chapter 26 covers assessing the suitability of using infiltration to dispose of surface water runoff, testing and infiltration design methods.
- ▶ Chapter 26 provides guidance on design methods for water quality management.

24.1 INTRODUCTION

The preliminary calculations required to design a SuDS scheme to meet the hydraulic design criteria are:

- 1 **for greenfield and previously developed sites:** an estimate of the peak runoff rates and runoff volumes from the site in its greenfield state
- 2 **for previously developed sites:** an estimate of the peak runoff rates and volumes from the site in its previously developed state

These runoff rates will dictate the rate to which the runoff from the site should be controlled (as required by water quantity standard 2); and the calculation methods are set out in **Sections 24.3 and 24.5**.

These runoff volumes will dictate the allowable volume of runoff that can be discharged from the site (as required by water quantity standard 1); and the calculation methods are set out in **Sections 24.4 and 24.5**.

- 3 **for the proposed development:** an estimate of the runoff rates and volumes from the site in its developed state (**Section 24.6** for calculation methods), and how these should be adjusted to take account of potential future development and climate change (**Section 24.7**).

The runoff rates calculated for the proposed development will exceed the allowable discharge rates. Therefore, the SuDS design will need to include attenuation storage that will fill during rainfall events and/or infiltration components that mean that runoff does not occur. Calculation methods for attenuation storage are set out in **Section 24.9**.

The volume of runoff from the proposed development will also exceed the allowable discharge volumes. Therefore, the SuDS design will need to “use” the runoff (**Chapter 11**), infiltrate the runoff (**Chapter 25**) and/or store and tightly control an additional storage volume, referred to as Long-Term Storage (**Section 24.10**).

Where runoff volumes before development are low, this reflects the presence of more permeable soils. Therefore, although the estimated runoff volumes for the proposed development will be significantly greater, it should be possible to infiltrate a large proportion of this volume, provided that the groundwater is adequately protected (**Section 26.3**).

Designing the site to deliver adequate Interception (the prevention of runoff from the site for the majority of small rainfall events), as required by water quantity standard 1, is set out in **Section 24.8**.

- ▶ **Section 24.11** describes how to design drainage components that convey flow from one point on the site to another, up to a specified standard of service
- ▶ **Section 24.12** describes design methods for managing flows greater than this standard (ie designing for exceedance flow management).

24.2 RUNOFF ESTIMATION METHODS

24.2.1 An overview of available methods

There are several methods that can be used for estimating peak runoff rates and runoff volumes. Catchment runoff models, adjusted for the size of the site, tend to be used for predicting runoff from greenfield sites. When predicting the response of a developed site, models that represent the existing or proposed drainage system are required, taking account of conveyance and storage capacities of drainage components, flow controls and areas likely to flood and store water during extreme events.

The available methods are summarised in **Table 24.1** and described in the sections in this chapter as indicated. Drainage approving bodies may specify the methods that they require to be used for drainage submissions, or they may leave method selection to the designer. The required approach should always be checked at an early stage in the design process.

Some of these methods are old and there are more recent methods likely to produce better runoff estimates. However, these older methods tend to be simpler and are not dependent on software that has to be purchased. Where the expertise and software required to design and approve systems using the more recent methods is available, the newer methods should be used. Different methods are likely to give different runoff estimates, which could influence the storage volumes required for the drainage system and thus the scheme cost and viability.

24.2.2 Runoff areas to be used in calculations

The runoff area used in any of the runoff estimation methods should be consistent; for example, if the whole site area is used in the greenfield runoff rate calculations, the whole site should also be represented in the runoff calculations for the proposed development. If there is a landscaped area in the developed scenario that discharges directly to receiving waters and does not contribute to the drainage system (so is excluded from the calculations) then this area should also be excluded from the greenfield calculations.

24.2.3 Rainfall to be used in calculations

In order for assessments to be made of the likely rate and volume of runoff from a developed site or catchment, a depth of rainfall and/or rainfall profile is required. This is also required for assessment of greenfield rates if a rainfall–runoff modelling approach is adopted. To date, design rainfall event methods have normally been used that are based on the use of fixed rainfall depths for different return period events and standard rainfall profiles (eg the FEH depth-duration-frequency rainfall model – CEH, 1999). The alternative approach, which is becoming more common for some applications, is to use a continuous time series of rainfall to generate a time series of flows from which frequency curves can be generated. These rainfall time series can come from observed rainfall data, if the series is long enough and appropriately quality assured and calibrated, or can be statistically generated from a number of observed datasets. The two approaches are described in the following sections.

TABLE 24.1 Summary of runoff estimation methods

Runoff estimation method	Reference	Greenfield site		Developed site		Section ref
		Peak runoff rate	Runoff volume	Peak runoff rate	Runoff volume	
FEH ReFH2	Kjeldsen (2007)	✓ ¹	✓ ¹	✓ ³	✓ ³	24.3.1
FEH statistical method	Kjeldsen <i>et al</i> (2008)	✓ ¹				24.3.1
IH124	Marshall and Bayliss (1994)	✓ ^{1,2}				24.3.2
FSSR16	NERC (1985)		✓ ^{1,2}			24.4
Modified rational method	HR Wallingford (1981)			✓ ³		24.6.2
Wallingford – Fixed	HR Wallingford (1981)			4	4	24.6.3
Wallingford – Variable	Packman (1990), Osborne (2009)			✓	✓	24.6.3
UKWIR	UKWIR (2014)			✓	✓	24.6.3

Notes

- 1 The Environment Agency (through the joint EA/Defra/NRW/Welsh Government FCERM research and development programme) is currently undertaking research that will improve small catchment and plot-scale flood and hydrograph estimation. The intention is for the research and new methods to be available to practitioners in 2020. Some interim outputs are already available (Faulkner *et al*, 2012).

The research will deliver two approaches:

- a full hydrological analysis method, adapted for watercourses within small catchments (using FEH approaches, gauge records (including donors) and catchment descriptors)
- a specific plot-scale method with a free to access tool and input characteristic data

SuDS practitioners undertaking hydrological analysis from 2020 onwards should therefore check for the latest guidance and recommendations on the Environment Agency R&D web pages or the FEH development pages (hosted on the CEH website).

- 2 FEH methods are preferred.
- 3 Simple method, relevant for initial design estimates and very simple sites.
- 4 No longer recommended, but included here as it is still used in current modelling software packages.

Design rainfall

The standard approach currently used by drainage engineers is to use design rainfall events with specific return periods and durations. These were developed originally in the *Flood Studies Report* (FSR) (NERC, 1975) and have been developed further in the *Flood Estimation Handbook* (FEH) (CEH, 1999), and subsequent revisions (Stewart *et al*, 2013). They are routinely used as inputs to greenfield runoff and development drainage models from which flow hydrographs and drainage system performance assessments are then produced.

The FSR/FEH methods provide two profiles: a summer (peakier, with higher intensities) profile and a winter (flatter, with lower intensities) profile. EA/Defra research into rainfall frequency found that seasonal adjustments were applicable to all durations (Stewart *et al*, 2013). Osborne (2012) suggests that, for shorter duration events, winter events should have a smaller total depth.

Summer profiles usually give the worst-case scenarios for sizing piped systems or components receiving direct runoff from impermeable surfaces. Winter profiles generally give the worst case when sizing storage and downstream attenuation components. This is because of the increased runoff generated for winter events due to higher catchment wetness parameter values, which result in larger storage requirements. Although the FEH can be used for durations as short as 30 minutes, flood estimation guidance from the EA (2015) currently recommends that, for shorter durations, FSR rainfall statistics should be used to scale down the corresponding FEH 1-hour rainfall.

The critical duration is the length of rainfall event that results in the greatest flow rate, flood volume or flood level (depending on the purpose of the analysis) at a particular location. It is common for the critical

duration to be different at different points in the drainage system, with different SuDS components having different critical durations. This results in a site designer having to use a matrix of events of different return periods and durations to ensure that the design criteria for the system are met at all points. Return periods from 1:1 year to 1:100 years (or 1:200 years in Scotland) and durations from 15 minutes to 48 hours are often required to be assessed.

For greenfield sites, the event duration is not always required, as the estimation of the peak rate of runoff can be based on correlation equations that do not use event rainfall data as an input. However, there are some greenfield runoff models that generate a flow hydrograph from rainfall and, for these, the design event duration is estimated by the models.

Time series rainfall

Continuous rainfall data is a time series of observed (where available) or statistically generated rainfall depths (where observed records are unavailable or too short for the required application). Time series rainfall is not yet routinely used in the design of surface water management systems, due to its inconsistent availability, cost and processing demands. However, in the case of SuDS, time series rainfall allows more accurate estimates of runoff, taking account of infiltration, soil moisture storage and release and evapotranspiration processes. It also allows estimates of subannual event frequencies and associated durations and velocities, which is useful for the assessment of treatment effectiveness.

The length of the rainfall series should be long enough to ensure that the complexity of rainfall characteristics and related aspects, such as dry periods, are properly taken into account. A minimum series length of at least twice, and preferably three times, the design return period of the system is recommended.

24.3 GREENFIELD SITES: PEAK RUNOFF RATE ESTIMATION

Estimated peak runoff rates for the development site in its greenfield condition for a range of return periods are normally used to define the discharge limits for a new development site.

For greenfield sites, the peak runoff rate for any particular return period is related to the site's catchment characteristics (including soils). The values derived from any analysis should be regarded as approximate, because prediction of runoff from very small catchments will always be imprecise. Furthermore, all runoff estimation methods have been developed using river flow information from much larger catchments than the average development site. However, it has been demonstrated in recent research that there is little evidence that the FEH methods perform less well at smaller scales (Faulkner *et al*, 2012). It should be understood that the overall objective of using an agreed method is to provide a consistent and reasonable estimate upon which storage design can be based, rather than finding the exact runoff rate for any specific site (which is not possible).

The current approaches recommended for calculating greenfield runoff rates are described in the following sections. However, the method used at a particular site should always be agreed with the drainage approval body. Further guidance is provided in EA (2015) and Faulkner *et al* (2012).

FEH methods should be the preferred approach for developing runoff estimates for use in surface water management design, but their use currently depends on access to the FEH documentation and software and suitable hydrological modelling expertise. Where FEH tools are not available, and with agreement of the approving body, the Marshall and Bayliss (1994) approach can be used as an alternative method. From 2017, new recommendations for estimating greenfield runoff rates and volumes will be published (see Note (1) for **Table 24.1**).

It should be noted that Marshall and Bayliss (1994) is more likely to underestimate runoff rates than FEH methods, potentially leading to overdesign of attenuation storage components (Faulkner *et al*, 2012).

24.3.1 Flood Estimation Handbook (FEH)

The FEH methods of flood estimation (CEH, 1999), together with subsequent revisions, superseded the FSR (NERC, 1975) as standard practice for catchment rainfall and runoff analysis in the UK in 1999. Two main approaches for flood frequency estimation are provided:

- statistical method
- rainfall-runoff method (ReFH2)

These are described in the following sections.

FEH statistical method

The FEH statistical method allows estimation of the complete flood frequency curve in any gauged or ungauged catchment in the UK. Details of the updated method can be found in Kjeldsen *et al* (2008), and only a brief summary is presented here.

**EQ.
24.1**

Estimating the flow frequency curve using the FEH statistical method

The peak rate of runoff for any return period is determined by multiplying an “index flood” by a return period “factor”. For example, for the 1:100 year peak runoff rate, this is:

$$Q_{100} = Q_{med} \times GC_{100}$$

where:

- Q_{100} = 100 year peak runoff rate
- Q_{med} = index flood
- GC_{100} = 100 year growth curve factor

The index flood can either be computed from relevant observed flows, or can be estimated using an equation where it is related to a number of hydrological parameters termed “catchment descriptors”, which are digitally mapped for the UK (and provided as part of the FEH software). On the FEH CD-ROM 3 catchment descriptor map, average values are provided for the catchment area associated with each defined point along a watercourse. It is not, therefore, possible to determine the relevant descriptors for a specific development site using the current software. The CD-ROM is to be replaced by a web-based delivery service in autumn 2015, and it is planned that future updates will provide some catchment descriptors relevant to individual points or small areas.

For catchments or sites smaller than 50 ha (0.5 km²), it is suggested that runoff estimates should be made using the methods applied to the nearest suitable catchment above this threshold for which descriptors can be extracted, and then the rates are scaled down by the ratio of catchment area to plot size (Faulkner *et al*, 2012). The decision to translate FEH estimates from catchment scale to plot scale should be accompanied by an assessment of whether the study site is sufficiently representative of the surrounding catchment area. In particular, checks should always be made of the HOST soil class suggested by FEH, by inspection on site. Alternatively, if the FEH software is not used, then an agreed site-specific set of parameters can be used.

The flood frequency (flows for different return period events) estimation procedure therefore consists of three stages:

- 1 **Estimate the index flood** (defined as the median annual maximum flood, Q_{med}), either from observed annual peak flow data or from catchment descriptors. The catchment descriptor equation is given in **Equation 24.2**. The Q_{med} estimate can be improved where flows are available from nearby, similar gauged catchments using methods published by Kjeldsen (2014).
- 2 **Derive an appropriate growth curve.** At a gauged site, flood frequency analysis techniques are applied to either gauged annual maximum and/or peaks-over-threshold flood peak data where available. At an ungauged site, the FEH pooling-group software package, WINFAP, is used to create

a pooling-group of “hydrologically similar” gauged catchments (ie catchments showing similarity with regard to key catchment descriptors: catchment area (AREA), standard annual average rainfall (SAAR), flood attenuation from reservoirs and lakes (FARL) and floodplain extent (FPEXT)). Flood growth curves are then created through analysis of the pooling-group flood peak data.

3 Evaluate the full flood frequency curve. The flood frequency curve is estimated as the product of the index flood and the growth curve. Peak flow rates for each return period are read from this flood frequency curve.

EQ.
24.2

FEH statistical method: catchment descriptor equation

$$Q_{med.cds} = 8.3062 AREA^{0.8510} \times 0.1536^{(1000/SAAR)} \times FARL^{3.4451} \times 0.0460 BFIHOST^2$$

where:

- $Q_{med.cds}$ = median annual maximum flood estimated from catchment descriptors
- $AREA$ = the area of the catchment in km²
- $SAAR$ = Standard Average Annual Rainfall for the period 1961–1990 in mm
- $FARL$ = a measurement of the attenuation influence of water bodies (eg lakes) in the catchment; it is unlikely that $FARL$ will be relevant for development site runoff estimation, so this factor becomes 1.0 and therefore drops out
- $BFIHOST$ = a measure of the level of baseflow (ie ongoing runoff) from the catchment; the measure is provided within the FEH software or, if a suitable site soil assessment is available, then IH126 **Table 2.12** (Boorman *et al*, 1995) can be used to allocate a HOST category to the site soils, and IH126 **Table 3.4** can then be used to obtain a corresponding value for $BFIHOST$.

Revitalised FSR/FEH rainfall-runoff method (ReFH2)

The revitalised FSR/FEH rainfall-runoff method (ReFH) was developed as an event-based approach to design flood estimation and replaced the previous FSR method. Details of the method can be found in Kjeldsen (2007) and subsequent updates (CEH and WHS, 2015). The current version of the method, ReFH2, also includes a component for incorporating the influence of the runoff from paved surfaces on runoff rates and volumes described by Kjeldsen *et al* (2013) (**Section 24.5**). Only a brief summary is presented here. The method uses an event-based rainfall-runoff model, to convert design storm events of appropriate duration and return period into a corresponding design flood event of similar return period. As this method produces runoff hydrographs, it will provide an estimate of greenfield runoff volumes as well estimates of the peak flow rate.

The ReFH model has four model parameters controlling the following:

- hydrological losses (maximum soil capacity, C_{max})
- routing using a unit hydrograph (time to peak, T_p)
- baseflow recharge (BR)
- baseflow lag-time (BL)

and two initial conditions:

- initial depth of water held in the soil (C_{ini})
- initial baseflow at the start of an event (BF_0)

The four parameters and two initial conditions are estimated using catchment descriptors available from the FEH CD-ROM 3 software. The design storms are generated using the FEH rainfall depth-duration-frequency (DDF) model (Faulkner, 1999), also included within the ReFH2 software package.

For catchments smaller than 50 ha (0.5 km²) and small plots of land, it is currently recommended that the model is applied to the nearest suitable catchment above this threshold for which descriptors can be derived, and then the hydrographs are scaled down by the ratio of catchment area to plot size (Faulkner *et al*, 2012). Alternatively, the new ReFH2 software package also includes parameter equations for plot-scale application.

As with the statistical method, the decision to translate FEH estimates from catchment scale to plot scale should be accompanied by an assessment of whether the study site is sufficiently representative of the surrounding catchment area. In particular, checks should always be made of the soil class suggested by FEH, by inspection on site.

The original ReFH1 method is not recommended for use to predict the response of greenfield catchments defined as permeable ($BFI_{HOST} > 0.65$), because it is likely to underpredict the catchment response. Through revised initial conditions, the ReFH2 method has addressed this limitation (CEH and WHS, 2015)

24.3.2 Flood estimation for small catchments (IH124)

The Marshall and Bayliss (1994) approach was the result of a study aimed at improving the characterisation of flood response on small catchments (for areas less than 25 km²), especially on relatively permeable, dry, partly urbanised catchments. They presented new equations for time to peak based on FSR catchment characteristics for both part-urban and rural catchments. The study also introduced a revised version of the FSR regression equation for the mean annual flood (Q_{BAR}), based on gauged records for 71 small rural catchments. However, unlike the catchments used in the same study for the investigation of flood response, many of these smaller 71 catchments were upland, relatively wet and impermeable. Only nine had SAAR values of under 800 mm, while 30 catchments were in high SAAR areas (over 1500 mm).

The flood frequency (flows for different return period events) estimation procedure consists of three stages, as for the FEH approach:

1 Estimate the Q_{BAR} (mean annual flood)

The IH124 equation for Q_{BAR} is given in **Equation 24.3**.

EQ. 24.3 IH124: Catchment descriptor equation

$$Q_{BAR(rural)} = 0.00108 \text{ AREA}^{0.89} \times \text{SAAR}^{1.17} \times \text{SOIL}^{2.17}$$

where:

- $Q_{BAR(rural)}$ = mean annual flood (a return period in the region of 2.3 years)
- AREA = area of the catchment in km²
- SAAR = Standard Average Annual Rainfall for the period 1941–1970 in mm
- SOIL = soil index, which is a value found from the FSR soil maps or the WRAP map of the Wallingford procedure, and represents an estimate of the proportion of runoff from the catchment surface*

Where the site is less than 50 ha, the formula should be applied for 50 ha and the result factored based on the ratio of the actual site area and the applied area (50 ha).

* If a reliable surface soils class map of the site is available, then IH126 **Table 2.12** (Boorman *et al*, 1995), can be used to allocate a HOST category to the site soils. IH126 **Table 4.16** can then be used to obtain a corresponding value for SPR (note this is stated as a percentage, rather than a proportion so will need to be divided by 100). The extra detail provided by HOST is generally likely to provide an improved estimate of SPR than using the coarse categorisation of the five SOIL categories, although it should be recognised that SPR_{HOST} was not originally derived for use in the IH124 equation, and Appendix 5 of Kellagher (2013) should be referenced for further guidance on this issue.

2 Select an appropriate growth curve

Q_{BAR} can be factored by the UK FSR regional growth curves (NERC, 1977) for return periods < 2 years and NERC (1993) for all other return periods to obtain peak flow estimates for required return periods.

These regional growth curves are constant throughout a region, whatever the catchment type and size. In reality it is likely that growth curves become steeper for smaller catchments, so the regional curves may tend to underestimate high return period flows potentially leading to overdesign of attenuation storage components.

The hydrological regions and corresponding growth curves are given as **Figures 24.1 and 24.2, and Table 24.2.**

3 Evaluate the full flood frequency curve.

Peak flow rates for each return period can then be estimated as the product of Q_{BAR} and the relevant growth curve factor.



Figure 24.1 Hydrological areas

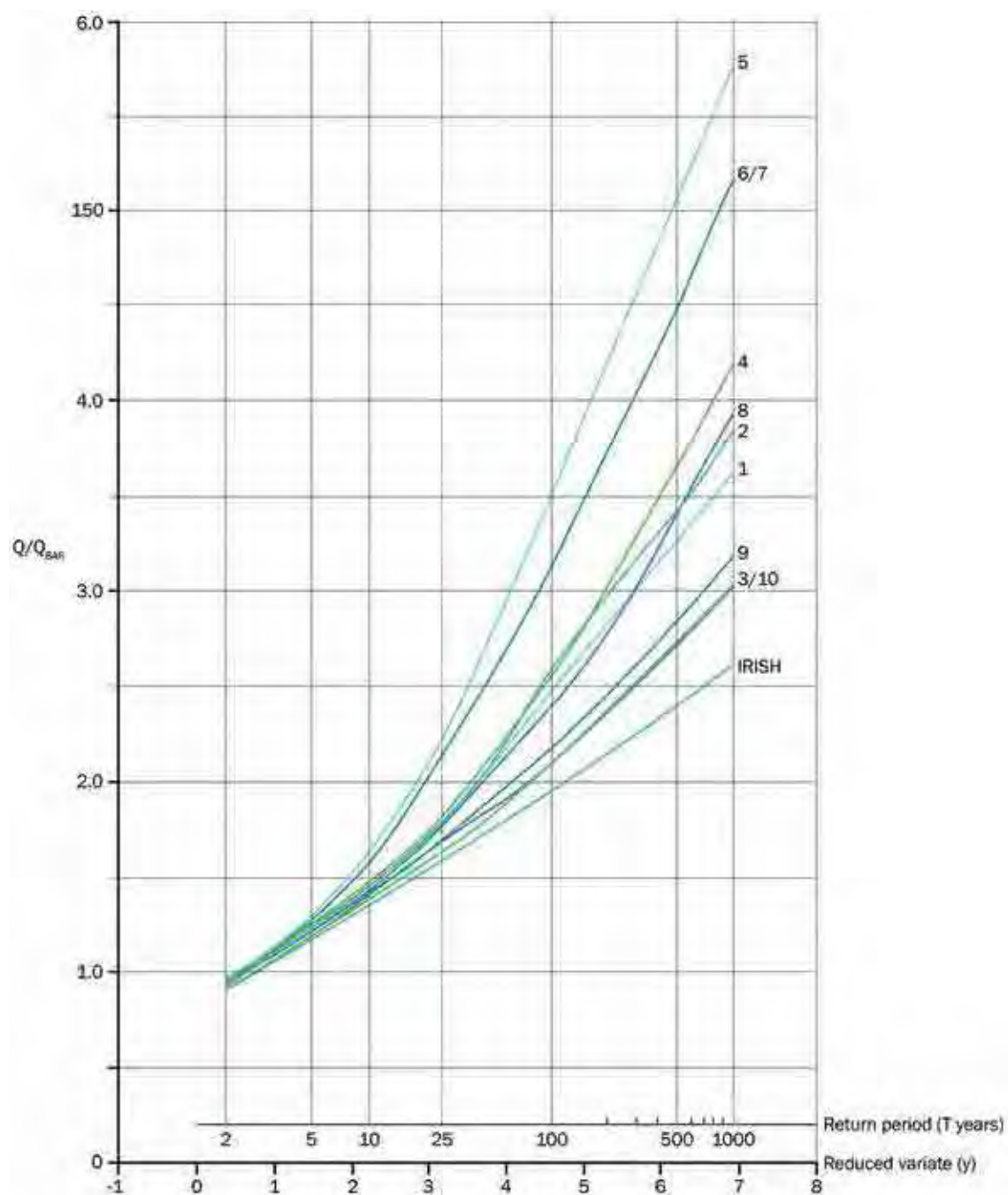


Figure 24.2 UK and Ireland growth curves (after NERC, 1975)

TABLE 24.2 UK and Ireland growth curve factors (after NERC, 1993)

Hydrometric area	Return period								
	1 ¹	2	5	10	25	30 ²	50	100	500
1	0.85	0.90	1.20	1.45	1.81	1.99	2.12	2.48	3.25
2	0.87	0.91	1.11	1.42	1.81	1.99	2.17	2.63	3.45
3	0.86	0.94	1.25	1.45	1.70	1.75	1.90	2.08	2.73
9	0.88	0.93	1.21	1.42	1.71	1.80	1.94	2.18	2.86
10	0.87	0.93	1.19	1.38	1.64	1.70	1.85	2.08	2.73
4	0.83	0.89	1.23	1.49	1.87	1.99	2.20	2.57	3.62
5	0.87	0.89	1.29	1.65	2.25	2.55	2.83	3.56	5.02
6/7	0.85	0.88	1.28	1.62	2.14	2.40	2.62	3.19	4.49
8	0.78	0.88	1.23	1.49	1.84	1.98	2.12	2.42	3.41
Ireland	0.83 ²	0.95	1.20	1.37	1.60	1.65	1.77	1.96	2.40

Notes

- 1 1 year return period growth curve factors are taken from NERC (1977)
 2 30 year (and 1 year for Ireland) return period growth curve factors are interpolated estimates

24.4 GREENFIELD SITES: RUNOFF VOLUME ESTIMATION

The greenfield runoff volume for a site is used to define the allowable runoff volume that can be discharged (at greenfield flow rates) from a development site, in order to protect downstream areas from increased flood risk due to the development. This is usually defined as the 1:100 year 6 hour duration design event, based on research by Kellagher (2002).

The use of a single event provides a simple, generic approach. The 6 hour duration event is based on the need to provide adequate protection for small to medium-sized watercourses that tend to be most at risk from the effects of urbanisation. An alternative criterion may be specified locally.

The objective of this criterion is to allow original greenfield runoff rates to continue, while also controlling the runoff volume. The alternative is to accept higher volumes of discharge, but to limit all the runoff to much lower flow rates (eg < 2 l/s/ha or as agreed with the local drainage approving body and/or environmental regulator), otherwise downstream flood risk is likely to rise.

An evaluation of the greenfield runoff volume for the 1:100 year 6 hour event can be avoided by using a simple method to estimate the difference in runoff volume between the developed and greenfield conditions (**Section 24.10**).

Greenfield runoff volumes can be calculated in one of two ways:

- 1 Using equations that predict the proportion of runoff (percentage runoff: PR) that occurs from the site for the design event.

A simple assumption can be made that the proportion of rainfall that runs off a greenfield site is not dependent on catchment wetness, and is thus equal to the SPR (standard percentage runoff) value for the site soil type. The assumption that SPR is the runoff proportion is a reasonable approximation for extreme events, even though the actual runoff is also related to catchment wetness.

SPR or PR values are then used to determine the runoff volume by multiplying them by catchment area and rainfall depth:

$$\text{Runoff volume} = (\text{SPR or PR}) \times \text{catchment area} \times \text{rainfall depth}$$

The PR model from NERC (1985) is presented in **Equation 24.4**.

- 2 From design event runoff hydrographs (where rainfall-runoff methods are being used (**Section 24.3.1**). This should be for the 100 year, 6 hour event. The difference in approach between 1 and 2 is that, in the rainfall-runoff model, the standard and dynamic components of percentage runoff are computed explicitly based on the design estimate of initial soil water content and the dynamic evolution of soil water content during the course of the rainfall event.

An important issue to note is the crucial influence of soil type on runoff volume. In practice, this indicates that developments on sandy soils create significant extra runoff volume compared to the pre-development condition (but it should be possible to manage this volume using infiltration), while developments on clays generate relatively small amounts of extra runoff (where infiltration design is less likely to be appropriate).

EQ. 24.4 Fixed percentage runoff model (from NERC, 1985)

The fixed percentage runoff method correlates runoff volume (as percentage runoff) with soil type, storm depth and other easily derived parameters:

$$PR_{RURAL} = SPR + DPR_{CWI} + DPR_{RAIN}$$

where:

- PR_{RURAL} = total percentage runoff for the greenfield catchment for a particular event
 SPR = standard percentage runoff, which is the fixed component of the percentage runoff and can be computed as either a function of the five soil class fractions defined by the FSR WRAP map:

$$SPR = 10S_1 + 30S_2 + 37S_3 + 47S_4 + 54S_5$$

or from the SPR values for each of the FEH HOST soil class fractions:

$$SPR = SPR_1HOST_1 + SPR_2HOST_2 + \dots + SPR_{29}HOST_{29}$$

- DPR_{CWI} = the dynamic component of the percentage runoff. This parameter reflects the increase in percentage runoff with increasing catchment wetness. The catchment wetness index (CWI) is a function of the average annual rainfall (**Figure 24.3**).

$$DPR_{CWI} = 0.25 (CWI - 125)$$

The DPR_{RAIN} is the second dynamic component that increases the percentage runoff from large rainfall events.

$$DPR_{RAIN} = 0.45 (P - 40)^{0.7} \text{ for } P > 40 \text{ mm (where } P \text{ is event rainfall depth)}$$

$$DPR_{RAIN} = 0 \text{ for } P \leq 40 \text{ mm}$$

continued...

continued from...

EQ. 24.4 **Fixed percentage runoff model (from NERC, 1985)**

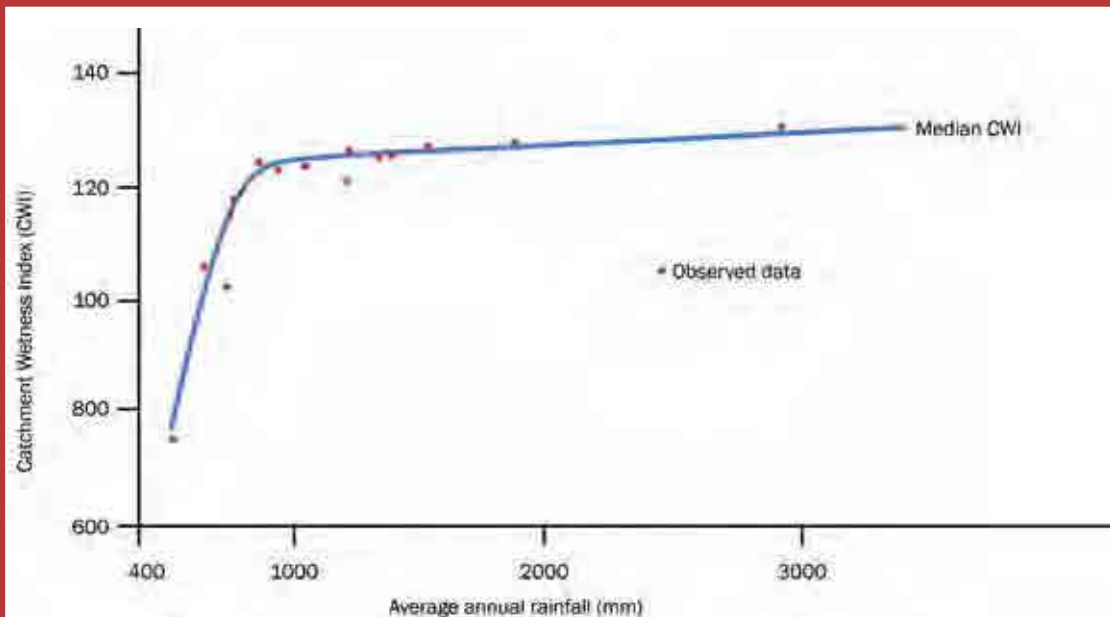


Figure 24.3 Catchment wetness index (CWI) vs Standard Average Annual Rainfall (SAAR) (from NERC, 1975)

24.5 PREVIOUSLY DEVELOPED SITES: PEAK RUNOFF RATE AND RUNOFF VOLUME ESTIMATION

Where a site has been previously developed, there may be agreement that discharge limits can correspond to rates that exist for the current state of the site (or a proportion of those rates). The preferred position should be to aspire to meet greenfield runoff rates and volumes, and any relaxation of this should be subject to an assessment of the current and future capacity of the receiving sewer or watercourse and agreement with the environmental regulator, drainage approving body and/or relevant sewerage company. In many cases, runoff volume may be as important as flow rate in terms of protecting receiving water body flood risk. Local policies, specifically strategic Flood Risk Assessments should be checked with respect to runoff control requirements for previously developed sites.

Runoff characteristics for a previously developed site can be estimated in a number of ways:

- 1 Any land that has been previously developed is likely to have had a system in place to drain surface water runoff from the site. This drainage system may or may not have included storage and flow control systems. Where any drainage system is still operational, peak flow rates at the outfall for the relevant return periods (usually 1:1 year, 1:30 year and 1:100 year) can be demonstrated by producing a simulation model that includes an accurate representation of the drainage system and site area contributions – thus allowing derivation of an appropriate head–discharge relationship at the outfall.

It is recognised that existing drainage systems will probably be overwhelmed for the 1:30 and 1:100 year events and therefore the actual rate of discharge from the site in such scenarios is likely to be increased by overland flow contributions or surcharging. However, these effects should not be accounted for, and the discharge limit should be based solely on the flow rate from the piped system (thus providing a conservative estimate).

- 2 Where records of the previously developed system are not available (so that the hydraulic characteristics of the system cannot be determined) or where the drainage system is not in reasonable working order (ie broken, blocked or no longer operational for other reasons), then one of the following approaches can be adopted:
 - a The first approach assumes that the runoff from the site is represented by greenfield response from impermeable soils. The methods for greenfield peak runoff estimation ([Section 24.3](#)) and volume estimation ([Section 24.4](#)) should therefore be applied using a high runoff soil type that

better represents the high levels of runoff that take place from developed surfaces (eg FSR Soil Type 5 or equivalent lowest permeability soil type for the runoff estimation method used in the design). This approach should only be used if the site is predominantly urbanised, and it would not be appropriate for sites with, for example, permeable soils and limited development. In these situations greenfield runoff rates would normally be a more appropriate target.

- b Runoff from the site can be estimated using the urbanisation methods within the ReFH2 software. Using this method, the impervious area can be set to the area of the impervious surfaces in the development site.

24.6 THE PROPOSED DEVELOPMENT SITE: PEAK RUNOFF RATE AND RUNOFF VOLUME ESTIMATION

24.6.1 Introduction

The runoff from the proposed development surfaces will be required as inflows to the drainage system.

Site developments are characterised as having two main categories of surfaces: impermeable (paved and roof) areas and permeable (grassed and vegetated) areas. These surfaces have different runoff characteristics, so both need to be represented in calculations and models.

Surface water management systems should usually be designed to accommodate the predicted effects of future climate change by factoring the design rainfall intensities by a climate change uplift factor. This is discussed in [Section 24.7.1](#). They should also consider likely future development and urban creep on the site, and suggested factors are presented in [Section 24.7.2](#).

An *initial* assessment of the peak rates of runoff from developed surfaces can be made using either the simple “modified rational” method, described here or the ReFH2 urbanisation method, as described in [Section 24.5](#) for the previously developed site. These methods are useful for assessing peak flow rates for initial sizing of inlets and conveyance systems. However, a volumetric method using a simulation model is normally required for sizing of storage components, owing to the need to determine multiple critical durations for individual points in the drainage system. The modified rational method provides a direct estimate of runoff rate from rainfall intensity, whereas a runoff model is used within a hydraulic simulation model that also describes the routing and attenuation of the collection and conveyance system in order to output a peak flow rate.

Whether a peak flow estimation or a volumetric approach is used, there is a need to make assumptions regarding the proportion of runoff that takes place from both impervious and pervious surfaces for a specified rainfall event. This can be estimated based on fixed values, for example as suggested by WRc (2012), or based on a runoff model.

24.6.2 The modified rational method

The peak runoff rate can be estimated using the equation given in [Equation 24.5](#).

Volumetric and routing coefficients (C_v and C_R)

The coefficient of runoff was split into two terms when the modified rational method (HR Wallingford, 1981) was originally produced: the volumetric runoff coefficient, C_v (of the order of 0.6) and the routing coefficient, C_R , (of the order of 1.3). However, the routing coefficient (which addresses the fact that some parts of the site will generate flows to a downstream point faster than others) tends to be ignored.

For paved area runoff, the two coefficients are usually incorporated into a single term with a value of between 0.8 and 1.0 – depending on how effectively the catchment is drained and the level of impermeability.

An equivalent approach is required for the pervious area runoff, with the chosen coefficient reflecting the proportion of contributing and non-contributing pervious areas, the soil type, site gradient, event size, likely antecedent conditions etc.

Guidance on runoff proportions from extreme events for different surfaces is provided in NERC (1985).

WRc (2012) is the industry standard produced by water companies for adoption of drainage for new development. It proposes the use of 100% runoff from impermeable areas and 0% runoff from pervious areas. This is known to be suitably conservative for events of between 1:1 year and 1:5 year. However, it is likely to be less appropriate for larger events when the pervious areas start generating significant runoff. For standard developments that tend to have impermeability ratios of around 50–65%, this assumption is regarded as being acceptable, at least in terms of initial design and analysis, as it avoids having to use the more complicated runoff models.

EQ.
24.5

Modified rational method equation to determine peak flow rates

$$Q = 2.78 C i A$$

where:

- Q = design event peak rate of runoff (l/s)
 C = non-dimensional runoff coefficient which is dependent on the catchment characteristics

$$C = C_V C_R$$

- where C_V = volumetric runoff coefficient
 C_R = dimensionless routing coefficient

- i = rainfall intensity for the design return period (in mm/hr) and for a duration equal to the “time of concentration” of the network

- A = total catchment area being drained (ha)

Note: 2.78 is a conversion factor to address the rainfall unit being in mm/hr.

Rainfall intensity (i)

For the rational method to be used for design purposes, the rainfall intensity (i) for the design time of concentration needs to be known. This gives the maximum flow rate at a point in the network in order to size the conveyance component. The rational method assumes that the whole catchment contributes runoff to a point in the system that has the longest time of concentration of any drainage branch. The rainfall intensity for this duration is used to calculate the flow. Rainfall intensity–duration–frequency curves can be generated using the FSR, the FEH or from appropriate gauged autographic rainfall data.

Alternatively, for an initial assessment of the design of a pipe network (for pipe full flow), a constant rainfall intensity of 35 mm/hr can be assumed, or 50 mm/hr may be required by some approving bodies for a more conservative solution (May and Kellagher, 2004).

For design of piped urban drainage networks a time of entry of 3–5 minutes is assumed, and then the time taken to travel through the network from the furthest point in the catchment at the pipe-full velocity is added. Advice on this is provided in the modified rational method in Volume 4 of the Wallingford Procedure (HR Wallingford, 1981).

24.6.3 UK runoff models

UK runoff models

There are two methods currently recommended for use in the UK for predicting percentage runoff from developed areas for detailed design purposes:

- variable UK runoff model
- UKWIR UK runoff model

The “old UK” equation or “fixed UK” runoff model (HR Wallingford, 1981) was the original runoff model of the Wallingford Procedure, but this was officially replaced by the “variable UK” runoff model equation (Packman, 1990), although there are still models around that use the fixed runoff model. Revisions to the old equation are presented together with the variable UK runoff model equation in the Wallingford Procedure for Europe, (Kellagher, 2000), along with guidance on their use. The UKWIR runoff model (UKWIR, 2014) has only recently been developed, and industry is currently assessing its effectiveness. This latest model is intended to address some of the limitation of the variable UK runoff model and to take account of the more detailed HOST classes of soil that are available digitally across the UK. The research report provides a comparison of the three equations and data on their development, advantages and limitations.

The term “Wallingford Procedure” is usually used to describe the process or runoff modelling, simulation modelling (using hydraulic routing methods) and model verification, but only the runoff modelling (ie estimation of the rate and proportion of runoff from surfaces) is covered here.

All three methods are regression equations where each surface type is assigned a proportion of runoff. In the fixed UK runoff model, the runoff was a fixed coefficient (although the runoff coefficient value took into account antecedent conditions). Both subsequent equations have an runoff coefficient that increases as the ground gets wetter through the storm.

The model equations are summarised in the following sections.

Fixed UK runoff model

The “fixed UK” runoff model (or old UK equation) is a regression equation that was calibrated against a large number of events recorded in the UK and overseas. It is given in **Equation 24.6**.

This method is now outdated and no longer recommended. It has been replaced by later equations and is only included here for completeness, as it is still used in some industry models.

EQ.
24.6

Fixed UK runoff model

$$PR = 0.829 PIMP + 25 SOIL + 0.078 UCWI - 20.7$$

where:

- PR* = percentage runoff for the contributing catchment
- PIMP* = percentage impermeability (0–100) obtained by dividing the total directly connected impervious area (both roofs and roads) by the total contributing area
- SOIL* = an index of the water-holding capacity of the soil (0.15–0.50), based on the FSR WRAP parameter, obtained from FSR (NERC, 1975) or Wallingford Procedure mapping (HR Wallingford, 1981)
- UCWI* = urban catchment wetness index (design values are provided by referring to a figure relating *UCWI* to the annual average rainfall for that location (**Figure 24.3**).

Variable UK runoff model

The “variable UK” runoff model (or “new UK” equation) was introduced by the Institute of Hydrology as a replacement to the original fixed UK runoff model (old UK equation). The dataset used in developing a calibrated model was a subset of the same data used for the development of the previous approach.

This model provides a variable (increasing) percentage runoff during a rainfall event, in order to take account of changes in catchment wetness as the storm progresses. This aspect is particularly important for long duration events where losses reduce as the pervious surfaces become saturated. The model takes the form set out in **Equation 24.7**.

EQ. 24.7 Variable UK runoff model

$$PR = IF \times PIMP + (100 - IF \times PIMP) \times \frac{NAPI}{PF}$$

where:

- PR** = percentage runoff
IF = effective paved area factor (**Table 24.3**)
PIMP = percentage impermeability (0–100)
PF = soil moisture depth (mm)
NAPI = 30-day antecedent precipitation index (API) (depends upon the soil type)

This equation effectively divides PR into the two contributions from paved and pervious surfaces. The impervious area runoff is obtained by using an “effective contributing area” proportion, IF (ie from surfaces that run directly into the drainage system). The original recommended values of IF are given in **Table 24.3**. However, IF values have tended to be applied at around 0.7 in practice in most models.

TABLE 24.3 Recommended values of IF

Surface condition	Effective impervious area factor, IF
Poor	0.45
Fair	0.60
Good	0.75

The remainder of the paved area (the component (1 – IF) that does not run directly into the drainage system) is assumed to be a pervious surface and added to the pervious area.

The runoff from the pervious surfaces, and also any non-effective impervious surfaces, are represented by the second part of the equation with a runoff value of NAPI / PF. NAPI is a 30-day antecedent precipitation index (with evapotranspiration subtracted from the rainfall) that is given by a decay function equation with a decay coefficient, C, related to soil type as shown in **Table 24.4**.

Design values for NAPI have never been formally established, although the industry has generally accepted the findings of a paper by Margetts (2002). For more information on this topic, see UKWIR (2014). In practice the NAPI design values for SOIL type 1 and 2 are effectively zero. The values for SOIL type 3 and 4 are normally in the range of 10–25 mm and are related to SAAR (annual rainfall depth) for the location. It should be noted that the basis for the decay coefficient for SOIL type 5 has never been established and the decay value is generally regarded as being too high.

The moisture depth parameter, PF, should normally be set at 200 mm. There is very limited guidance on modifying this value, and caution is advised if any changes are made.

TABLE 24.4 Relationship between SOIL types and decay coefficient C

Soil types	C
1	0.1
2	0.5
3	0.7
4	0.9
5	0.99

UKWIR UK runoff model

The UKWIR UK runoff model (or UKWIR equation) is set out in **Equation 24.8**. It was developed in 2013 to address a number of limitations considered to apply to the variable UK runoff model equation. The following are some of the key limitations addressed:

- 1 Models calibrated using summer conditions generally underpredict runoff for winter conditions.
- 2 There is no scientifically approved value for the parameter NAPI for use with design storms.
- 3 There are improved soil characteristic datasets (HOST categories) available digitally for the UK.
- 4 The variable UK runoff model incorrectly assumes that runoff occurs from pervious areas for all events, however small the event.
- 5 It is not correct to assume that the non-effective paved surface component contributes runoff as a pervious surface.

EQ. 24.8 The UKWIR UK runoff model

$$PR = \sum_{n=1}^N \left[IF_n * PIMP_n + (1 - IF_n) * PIMP_n * \frac{PI_{pv}^\beta}{PF_{pv}} \right] + \left[(1 - PIMP_{total}) * \frac{((NAPI_s + PI_s)^{Cr} * SPR)}{PF_s} \right]$$

where:

- PR = percentage runoff
- $PIMP$ = percentage impermeability of the sub-catchment
- IF_n = effective impermeability factor for a particular paved surface type
- β = power coefficient for paved surface
- PI_{pv} = precipitation index for paved surface with rapid decay coefficient
- PF_{pv} = soil store depth for paved surface
- SPR = standard percentage runoff (for both WRAP and HOST soil classes)
- PI_s = precipitation index for pervious surface with decay coefficient
- $NAPI_s$ = antecedent precipitation index for a particular pervious surface type (with 30-day decay coefficient)
- Cr = power coefficient for pervious surface
- PF_s = soil store depth for a particular pervious surface type

As well as addressing the above issues, the development of the UKWIR equation has also taken into account the current and likely future development of runoff tools in urban drainage modelling for both 1D and 2D modelling, and the trend towards the use of continuous rainfall time series and away from design storms.

A description of the parameters in **Equation 24.8** is provided in **Table 24.5**. Other variables (that are embedded in these parameters) are described in UKWIR (2014). Any changes made to default values (eg for calibration scenarios) should be undertaken with all potential implications understood.

TABLE 24.5 UKWIR runoff equation: suggested parameter ranges

Parameter	Default value	Suggested range	Comment
<i>PR</i>	–	0–100	
<i>PIMP</i>	–	0–100	
<i>IF</i>	–	0.5–1.0	Values should be selected between 0.6 and 0.8, depending on how well drained the surface is and the level of impermeability
β	0.5	0.5–0.8	Paved power factor To increase runoff proportion quickly during the early part of the event
PI_{pv}	0	0–5	Initial wetness for paved surfaces Zero at start of event for design storms Non-zero value for continuous time series, but would always be close to zero at start of an event, as decay coefficient is small
PF_{pv}	10 mm	10–50 mm	“Storage” depth for paved and roof surfaces Could differentiate value based on surface type Altering this depth should be carried out in conjunction with the value of β used.
<i>SOIL</i>	–	1–5	WRAP/FSR soil types.
<i>HOST</i>	–	1–29	HOST soil classes
<i>SPR</i>	–	0.10–0.60	Soil runoff parameter (standard percentage runoff) Four SOIL and 29 HOST classes Lower limits applied to SPRHOST
PI_s	n/a	n/a	Decayed cumulative event rainfall Same decay function as NAPIs
$NAPI_s$	10 (for design rainfall, NB location specific)	–15 to +40 (depends on decay coefficient)	Antecedent precipitation index This can be negative where evaporation exceeds rainfall
<i>Cr</i>	0.8	0.8–1.0+	Pervious power factor Value linked to value of PFs Intended to provide greater influence of early rainfall compared to later rainfall during the event
PF_s	35	30–100	Soil store depth Choice is linked to value of pervious power factor

**BOX
24.1****A summary of the approach to modelling paved surfaces using the UKWIR UK runoff model**

- Runoff modelling of the paved components of a catchment has a fixed runoff component and a variable runoff component.
- The variable runoff component is a function of the rainfall depth and rainfall intensity.
- Each paved surface type (road, roof, indirectly drained areas) should be modelled with their own set of parameters:
 - The fixed runoff component for road surfaces should normally be set to have an effective impermeability of 0.5–0.65.
 - The fixed runoff component for roofs should normally be set to have an effective impermeability of 0.8.
 - The variable components should use a decay coefficient of 0.1, and a “soil” depth of 10 mm.
 - The rainfall depth power factor is set at 0.5 and aims to increase the influence of the early part of the storm in increasing the proportion of runoff.
- All parameters can be used to calibrate the model.

Paved runoff (UKWIR runoff model)

The paved component runoff model is very similar to the variable UK runoff model equation. It has a fixed runoff component ($IF \times PIMP$) and a variable runoff component $(1 - IF) \times PIMP$ (to represent rainfall that is “lost” on the paved surface). This second term is therefore separated from the pervious component of the model and routed with the paved surface runoff. It will therefore be more responsive to increasing wetness than the pervious runoff.

The increase in the rate of runoff during the event is now assumed to be non-linear to weight the increase in extra runoff to the early part of the storm depth using a power factor of 0.5. The use of a rapid decay coefficient means that the proportion of runoff is now related to the intensity of the rainfall.

As with the pervious component of the variable UK runoff model equation, the wetness of the paved surfaces is a continuously calculated value. It uses a 30-day analysis period, but the decay coefficient is set to 0.1 to ensure the wetness term (NAPI) rapidly reduces to zero after an event. NAPI is allowed to become negative, to prevent runoff from dry pervious catchments from taking place immediately rainfall commences.

The model allows more than one paved surface category and it is expected that three categories of paved surface would commonly be used (roads, roofs, indirectly drained paved areas); each potentially has its own set of parameters.

Pervious runoff (UKWIR runoff model)

The pervious runoff component is addressed in a similar way to the variable UK runoff model equation. This presumes that all the pervious area in a catchment contributes runoff based on an initial wetness measure, with an increasing proportion of runoff linked to rainfall depth. However, there are a number of significant differences built into the UKWIR equation.

Firstly, NAPI is a 30-day calculation, but it is not a function of soil type. The assumption has been made that antecedent wetness can be represented for all soil types by a single decay function. A value of 0.8–0.9 is proposed.

The second major difference is the calculation of NAPI, which now uses evaporation, and this can result in negative NAPI terms (acting rather like a soil moisture model). This has the important advantage of delivering a negative term for dry periods in summer. When the NAPI term is negative, it is assumed that this results in no runoff taking place from pervious surfaces. This approach was produced to provide an increase in differentiation between summer and winter runoff, thus addressing one of the key requirements of revising the variable UK runoff model.

Design values for NAPI were derived, and UKWIR (2014) should be referred to for details. However, an approximation of 10 mm could be used in the absence of detailed information or analysis.

**BOX
24.2**
A summary of the approach to modelling pervious surfaces using the UKWIR runoff model

- The equation uses hydrological soil parameters and methods that are currently available to, and understood by, the water industry.
- The use of HOST improves the resolution of soils information and this data can be imported digitally.
- All soils are modelled with one decay coefficient (default 0.8), with the proportion of runoff differentiated by the use of the soil specific term, SPR.
- All parameters can be modified to calibrate the model.
- Runoff from pervious surfaces are zero when the value of NAPI is negative (during dry periods and in the early part of a rainfall event).
- The rainfall depth power factor is set at 0.8, and aims to limit the influence of very large storm events in increasing the proportion of runoff.
- Each pervious surface type (specific soil category or estimated urban soil characteristic) should be modelled with its own set of parameters.
 - The minimum NAPI value is a function of the decay coefficient. It is suggested that a limit is set for the minimum negative value to around 15 mm.
 - The decay coefficient should be in the range of 0.7–0.9 for all soils.
 - The “soil” depth default is 35 mm, but this is linked to the rainfall depth power factor.
 - The minimum value of SPR should be 0.1. Although the maximum value for any soil class is 0.6, there may be circumstances (eg steep hillsides) when a slightly higher value might be justified.
 - The rainfall depth power factor default is 0.8.

Changing of the power factor and the “soil” depth should be considered together, so that a depth of 80–100 mm of NAPI + rainfall depth is needed to achieve a runoff of $1.0 \times \text{SPR}$ runoff (ignoring the effects of the decay coefficient).

24.7 CLIMATE CHANGE AND URBAN CREEP ALLOWANCES

When estimating runoff rates from development sites for design events, the computed flow should include an uplift to cater for the effects of climate change impacts on future rainfall intensities. To ensure that flood risk in the catchment does not increase with time, uplift factors on greenfield runoff rates should not be applied. Similarly drainage areas should be applied with urban creep factors to take account of a likely future increases in the impermeability of a site.

24.7.1 Climate change factors

Climate change uplift factors for rainfall intensities, peak river flows and sea level are normally specified by national government or the environmental regulator. They are regularly updated and therefore not provided in this document.

Peak river flow and sea level uplifts will be appropriate when considering the potential impact of receiving water body flood levels on the operation of the SuDS. Rainfall intensity factors will need to be applied to design rainfall depths for the developed site runoff assessment.

Current recommended climate change allowances should be based on the findings of UKCP09, with regional allowances and consideration of uncertainty, rather than fixed national allowances. For some regions, the upper end estimate from the UKCP09 impacts research is much higher than the suggested change factor, and in such scenarios it would be prudent to at least examine the sensitivity of SuDS designs, particularly for high-risk developments, to a range of possible climate change impacts.

The hyetograph rainfall intensity values for the design storm events should be increased by the relevant climate uplift factor for the required design life of the system.

Normally, residential sites use the 2085–2115 design horizon, but shorter horizons may be appropriate for commercial and industrial developments.

It should be noted that storage volumes will approximately increase by the square of any rainfall uplift factor. This means that a 10% increase in rainfall (an uplift factor of 1.1) will result in a 20% increase in storage (uplift factor of 1.21), while a 40% increase in rainfall will nearly double the storage required.

Other climate change projections, including reduced summer rainfall, may have implications for vegetation resilience and water quality performance of SuDS components (water quality criterion 2, [Section 4.2.3](#))

24.7.2 Urban creep factors

Urban creep is defined as any increase in the impervious area that is drained to an existing drainage system without planning permission being required, and therefore without any consideration of whether the capacity of the receiving sewerage system can accommodate the increased flow. For example, the construction of patios, conservatories, small extensions, paved driveways etc (post initial construction) may all result in an increase in surface runoff and therefore reduce the level of service of the drainage system.

To allow for future urban expansion within the development, an increase in paved surface area of 10% is often suggested if there is no specified value stipulated by the drainage approval body or planning authority.

24.8 DESIGNING FOR INTERCEPTION

Interception can be defined as the capture and retention on site of the first 5 mm (or other specified depth) of the majority of all rainfall events. Designing for Interception has two key benefits:

- 1 Runoff characteristics from the site will more closely reflect greenfield runoff behaviour (where runoff will not occur for the majority of small rainfall events) and this will help to protect the morphology and ecology of the receiving surface water body.
- 2 The pollution load to any receiving surface water body that could potentially be associated with the total runoff volume from all such small events will be retained on site – where it will have time to biodegrade and/or be acted on by natural treatment processes.

Interception can be delivered using one or a combination of processes:

- rainwater harvesting
- infiltration
- evapotranspiration using temporary shallow ponding or storage within the soil or upper aggregate layers

Any Interception method that potentially allows the transfer of contaminants to groundwater via the underlying soil pore water or soil matrix should follow the guidance in [Section 26.7](#).

Interception cannot be guaranteed for every rainfall event, due to the variability in evapotranspiration and rainfall through the year and the corresponding variability in soil moisture storage levels. Interception is far less likely to be achievable during extended wet periods where soils are saturated, so for any rainfall event, the design should have an associated probability of delivering Interception for any contributing impermeable area. Receiving streams and rivers are likely to be under greater stress during summer months (with lower available dilution levels and with flora and fauna less likely to be tolerant of rapid flow rates and high water levels at this time of year). It is therefore suggested that any criteria for compliance should differentiate between summer and winter; for example, for a 5 mm Interception depth, compliance for 80% of rainfall events could be required during summer months and 50% compliance during winter months.

Designing systems to achieve specific probabilities of compliance requires analysis using a model of the drainage system and continuous time series rainfall data, which may not be an approach that is accessible or usable by designers. Simple approaches are therefore set out in **Box 24.3**. Such approaches cannot evaluate the actual probability of compliance, but can provide a useful design aid. Alternatively, some assumed compliance scenarios are set out in **Table 24.6**.

**BOX
24.3****Simple approaches to Interception delivery and compliance assessment****Rainwater harvesting only**

Rainwater harvesting systems, whether designed for just reducing potable water demand or for surface water management as well, can be assumed to deliver effective Interception for the contributing surfaces.

Infiltration (where the system is designed for this purpose)

Where SuDS are designed to infiltrate more than 5 mm from the contributing catchment for all events, then Interception will be effectively delivered.

Evapotranspiration only

Assuming that rainfall is evenly distributed through the year, the effective monthly runoff contribution from 1 m² of paved surface is:

$$30 \text{ days} \times (700 \text{ mm}/365 \text{ days}) \times 50\% \text{ percentage runoff} = 29 \text{ mm of effective runoff}$$

(Note: the 700 mm represents the annual average rainfall, this can be varied depending on location; 50% runoff is appropriate for small rainfall events.)

The evaporative capacity of 1 m² of vegetative surface (without any infiltration capacity) for a peak summer month approximates to:

$$30 \text{ days} \times 3 \text{ mm/day} = 90 \text{ mm of effective rainfall}$$

(Note: the 3 mm/day is approximately the free surface evaporation rate in mid-summer for the UK.)

Therefore, the area for which Interception can theoretically be delivered by a 1 m² vegetated surface, in a peak summer month is:

$$90/29 = 3 \text{ m}^2$$

The effectiveness of the vegetated surface will be less if the average evapotranspiration capacity is less. In wet periods (whether in mid-summer or at other times), compliance will be less than 100%.

This analysis assumes that all rainfall needs to be retained. In practice, there are a number of events that are greater than 5 mm and in these cases the soil would not be expected to retain all the runoff. If one assumes that 25% of the runoff does not need to be retained to make an allowance for these larger events, this increases the paved area ratio served from 3 to 4.

Where the method is being applied to SuDS components with side slopes (eg swales or detention basins), an allowance should be made for the effective wetted width (ie the width of the surface that would be wetted when conveying runoff for the 5 mm rainfall depth event), rather than just taking the base of the component. For example, although the base of a swale might only be 1 m wide, the effective wetted width might be considered to extend over another 1–2 m. This would increase the area served by the system.

Allowance should be made for the variability in the rainfall, so it is suggested that temporary storage of 50 mm of rainfall is needed in the soil store beneath the vegetated surface. Assuming 20% voids ratio, the depth of available soil needed is 250 mm. Water at depths > 250 mm is much less likely to be lost through evapotranspiration.

Infiltration (where the system is not specifically designed for this purpose)

Unless the vegetated surface is lined, there will usually be small amounts of infiltration taking place from runoff events. A rate of infiltration of 1×10^{-7} m/s (which is a nominal rate and would not be considered for infiltration design specifically) represents approximately 260 mm of infiltration per month.

continued...

continued from...

BOX 24.3 Simple approaches to Interception delivery and compliance assessment

When this infiltration rate is combined with the evapotranspiration rate in summer (see above), this amounts to a combined depth of 350 mm which, when compared to an effective runoff depth of 29 mm per month, means that the system can deliver Interception for a contributing area of around 12 times the vegetated area. As for evapotranspiration, consideration should be given to the actual wetted area over which infiltration might be considered to occur for small events in non-saturated soils, provided that the design of the component encourages runoff across the full area before discharge.

Research on Interception by Kellagher (2014) showed that factors well in excess of 25 could be achieved using temporary storage depths (< 100 mm) above a 250 mm depth of well-prepared engineered soil and the use of marginal infiltration soil capacities. It can be seen that the infiltration rate is a crucial value for the analysis, so site testing should be undertaken to provide some justification of the rate assumed.

Wherever marginal infiltration is used to deliver Interception, the guidance on appropriate risk management design for Interception to protect groundwater should be followed (**Section 26.7**).

TABLE 24.6 Interception mechanisms

Systems	Interception methods that can be assumed to be compliant for zero runoff from the first 5 mm rainfall for 80% of events during the summer and 50% in winter
Green roofs	All surfaces that have green roofs
Rainwater harvesting systems	All surfaces drained to RWH systems designed to BS 8515:2009+A1:2013 whether for surface water management or just water supply, provided the RWH system design is based on regular daily demand for non-potable water.
Soakaway or other infiltration system ²	Areas of the site drained to systems that are designed to infiltrate runoff for events greater than a 1 month return period. Note: design of the infiltration system should be in accordance with Chapters 14 and 25 .
Permeable pavements ²	<p>All permeable pavements, whether lined or not, can be assumed to comply, provided there is no extra area drained to the permeable pavement.</p> <p>Where the pavement also drains an adjacent impermeable area, compliance can be assumed for all soil types where the pavement is unlined, as long as the extra paved area is no greater than the permeable pavement area.</p> <p>Where the infiltration capacity of the ground below the pavement is greater than 1×10^{-6} m/s, up to 5 times the permeable pavement area can be added as extra contributing area.</p> <p>Where the permeable pavement also drains an adjacent impermeable area and is lined, compliance cannot be deemed to have been achieved and extra downstream Interception components will be required.*</p>

continued...

continued from...

TABLE 24.6 Interception mechanisms

Systems	Interception methods that can be assumed to be compliant for zero runoff for the first 5 mm rainfall for 80% of events during the summer and 50% in winter
Filter strips/swales ²	<p>Roads drained by filter strips/swales, where the longitudinal gradient of the vegetated area is less than 1:100, are suitable for Interception delivery for impermeable surface areas up to 5 times the base of the vegetated surface area receiving the runoff.</p> <p>Components steeper than 1 in 100 cannot be deemed to provide Interception unless additional effective Interception design can be demonstrated.</p> <p>Any filter strip/swale that is unlined, has a gradient less than 1 in 100 and has an infiltration capability greater than 1×10^{-6} m/s can be assumed to comply with Interception for a contributing area up to 25 times the area, or a larger area where infiltration capacities and design characteristics allow.</p> <p>Interception cannot be deemed to have been provided for impermeable areas draining to a swale within 5 m from the swale outlet, unless the swale is flat and has a slightly raised outlet to create a temporary storage zone to encourage infiltration before runoff takes place.</p> <p>Greater loading ratios can be achieved by providing flat swales with greater temporary storage and infiltration, but these require detailed design, based on the use of appropriate continuous rainfall time series.</p>
Infiltration trenches ²	Roads drained by infiltration trenches can be considered to provide Interception.
Detention basins ²	<p>Areas of the site drained to detention basins with a flat unlined base (without specific provision for routing low flows directly to the outlet) can be assumed to comply, where the drained impermeable surface area is less than 5 times the vegetated surface area receiving the runoff for any soil type. The area of the basin that is assumed to contribute to Interception of runoff should be below the outlet level of the basin.</p> <p>Areas up to 25 times the base area of the basin can be assumed to meet Interception requirements where infiltration rates are greater than 1×10^{-6} m/s.</p> <p>Higher loading ratios can be achieved where specific provision is made for water being stored below the outlet pipe and higher infiltration rates exist. Where a basin is designed to infiltrate runoff, specific provision should be made for the upstream control of sediments to minimise risks of waterlogging, high maintenance costs and reduced component amenity value.</p>
Bioretention areas and rain gardens ²	Areas of the site drained to unlined bioretention components can be assumed to comply ¹ where the impermeable surface area is less than 5 times the vegetated surface area receiving the runoff. They can be designed to deliver Interception for larger areas, where suitable infiltration capacity is available.
Ponds	Areas drained by ponds (with a permanent water pool that is effectively maintained by the outlet structure) are not assumed to deliver Interception.

Notes

- Where individual components do not provide sufficient Interception for the area draining to them, Interception capacity can also be provided by downstream components. Detailed calculations will be needed to demonstrate compliance in this case.
- Where these systems are unlined or designed for infiltration, appropriate consideration should be given to the adequate protection of groundwater ([Chapter 4](#), [Table 4.3](#), and [Section 26.7](#)).

24.9 DESIGNING FOR ATTENUATION STORAGE**24.9.1 General description**

Attenuation storage is needed to temporarily store water during periods when the runoff rates from the development site exceed the allowable discharge rates from the site. Attenuation storage volumes are designed to drain at a rate controlled by the outlet structure.

Attenuation storage can be provided on site using structural controls (either above or below the ground surface), non-structural features and/or landscaped depressions. It can be provided by a storage component that is normally dry, or above a permanent water body – that is, a pond or wetland ([Figures 24.4 and 24.5](#)).

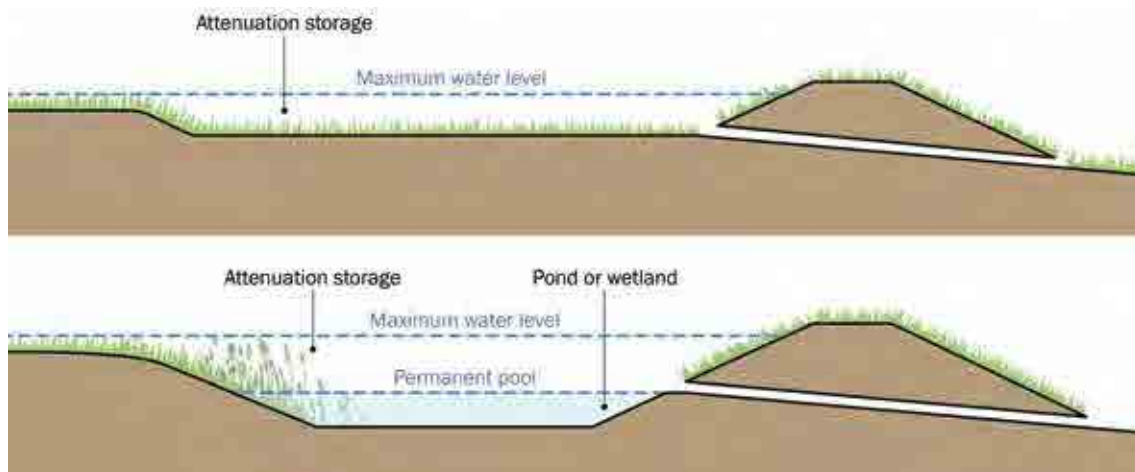


Figure 24.4 Attenuation storage in dry or wet components

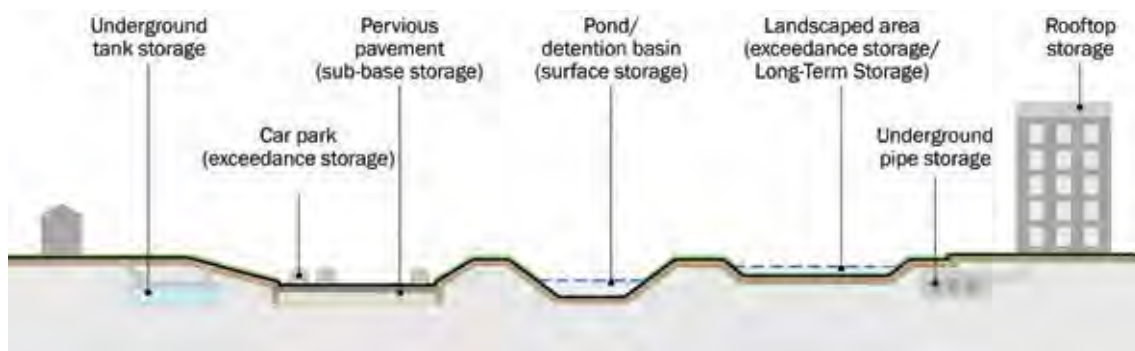


Figure 24.5 Examples of attenuation storage locations

Attenuation storage can be implemented either on line or off line. On-line storage uses a storage component through which all runoff from the upstream contributing catchment flows. Off-line storage is a storage component that is separate from the main drainage conveyance path, to which runoff is diverted when flow rates or levels exceed a threshold (**Figure 24.6**).

The advantage of off-line storage is that the volume of storage provided is minimised as the pass-forward flow rate is maximised before the storage starts filling. However, it does mean that the storage facility cannot combine as a treatment facility, as frequent events (that require treatment) will bypass the component and discharge directly downstream.

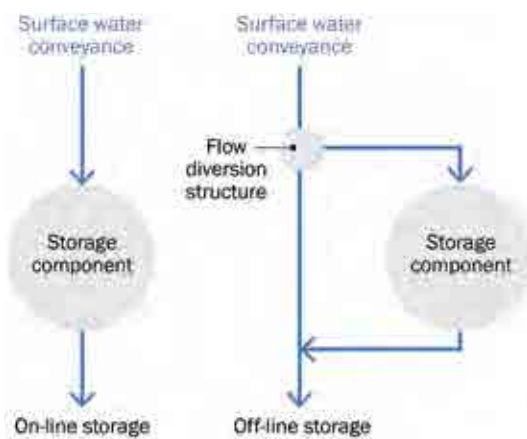


Figure 24.6 On-line vs off-line storage

24.9.2 Stage-storage design

A stage-storage curve defines the relationship between the depth of water and associated storage volume in a storage component. An example is given in **Figure 24.7**.

The storage can be estimated using Simpson's rule – a method for numerical integration (Atkinson, 1989). However, a less sophisticated approximation can be derived by averaging the areas for each height elevation over the full storage depth, and then integrating these – using **Equation 24.9**.

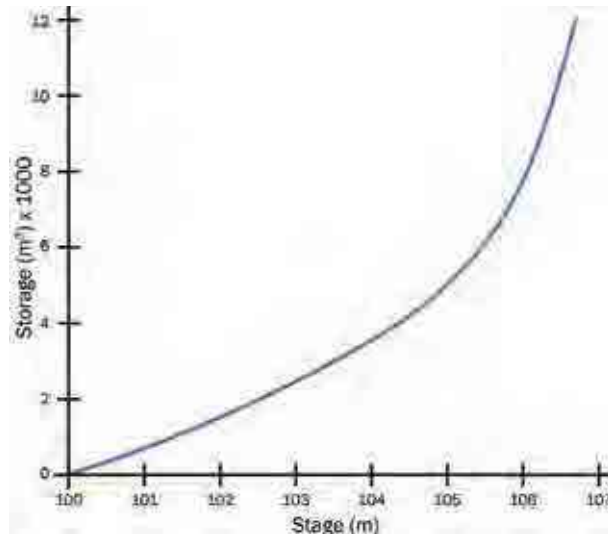


Figure 24.7 Example of a stage-storage curve

EQ. 24.9 Integration of storage volume from depth/area relationship

$$V_{1,2} = \left(\frac{A_1 + A_2}{2} \right) d$$

where:

- $V_{1,2}$ = storage volume (m^3) between elevations 1 and 2
- A_1 = surface area at elevation 1 (m^2)
- A_2 = surface area at elevation 2 (m^2)
- d = change in elevation between points 1 and 2 (m)

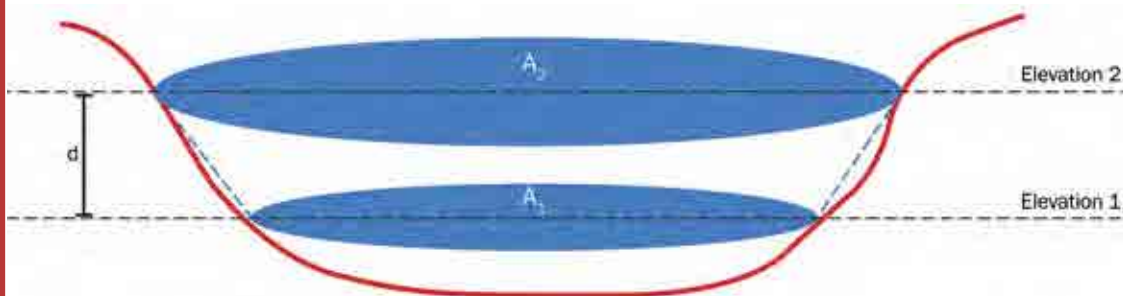


Figure 24.8 Schematic for estimating storage volume

24.9.3 Stage-discharge design

Simple outlet structures will only discharge at their maximum discharge rate at the maximum depth of water at which the water is stored. A stage-discharge curve (**Figure 24.9**) defines the relationship between the depth of water and the discharge or outflow from a storage facility. For simple assessments of storage requirements, this relationship can be accounted for by including a 25–30% extra storage allowance and using the design discharge flow rate. The relationship can be modelled explicitly using detailed simulation models.

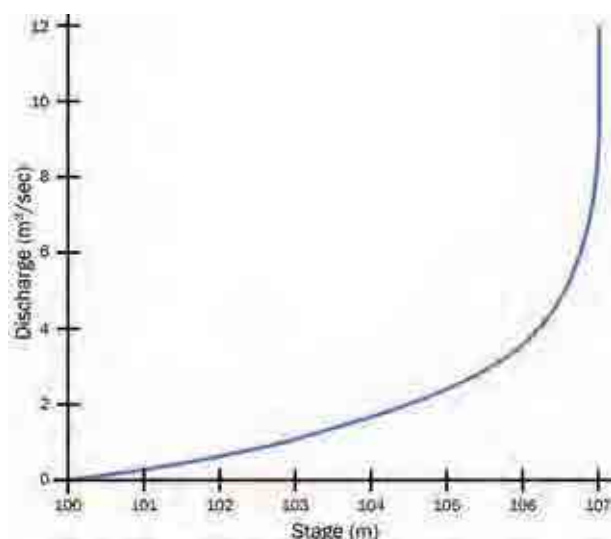


Figure 24.9 Example of a stage discharge curve

A storage component usually requires two outlets: a primary outlet and a secondary (or emergency) overflow route. A pipe, weir, orifice plate or other appropriate outlet is generally used for the principal outlet and an emergency spillway weir normally provides a bypass for floodwater for flows that exceed the design capacity of the component and as protection against blockage of the main outlet. The principal outlet may need to have a multiple flow control system, so that both 1:1 year and 1:100 year flow rates are adequately controlled. Guidance on the design of inlets and outlet controls is set out in **Chapter 28**.

24.9.4 Initial attenuation storage volume assessment

A method that gives an initial estimate of the required attenuation storage volume is provided in Kellagher (2013).

An alternative to the Kellagher (2013) approach is to develop a simple lumped simulation model of the storage system with a limiting discharge throttle and an overflow. The volume passing over the overflow is then the storage required for that specific event and throttle. A range of different storm durations will be required to determine the maximum spill volume. This method will underpredict the actual volume of storage needed as the head–discharge relationship for the hydraulic control is not being considered. Therefore, a further allowance of 25% should be applied to the first estimate of storage to allow for this approximation. An accurate model of the storage and conveyance system should be built at the earliest possible stage, to ensure that approximate estimates can be confirmed.

24.9.5 Detailed attenuation storage volume assessment

For most sites, a detailed model of the drainage system will be run at detailed design stage, with accurate depth storage and head discharge relationships represented accurately. This will enable checks to be made of the discharge rate controls and the adequacy of the proposed storages.

24.10 DESIGNING FOR LONG-TERM STORAGE

24.10.1 General description

Additional runoff volumes from developments can cause increases in flood risk downstream of the site, even where peak flows from the site are controlled to greenfield rates (**Section 3.1.2**).

Therefore, for extreme events, in addition to the standard for controlling the peak rate of runoff, there is also a standard that requires runoff volume control for the 1:100 year, 6 hour event (**Section 3.3.1**). This is particularly critical for catchments that are susceptible to flooding downstream of the proposed development.

The difference in runoff volume between the development state and the equivalent greenfield (or possibly pre-development state where this is considered to be acceptable) is termed the Long-Term Storage Volume. It is this volume that should be prevented from leaving the site (via rainwater harvesting and/or infiltration) or, where this is not possible, controlled so that it discharges at very low rates that will have negligible impact on downstream flood risk. Only the greenfield (or pre-developed) runoff volume should be allowed to discharge at greenfield (or pre-developed) rates.

Where there is extra volume generated by the development that has to be discharged (because there are no opportunities for it to be infiltrated and/or used on site), this volume should be released at a very low rate (eg < 2 l/s/ha or as agreed with the local drainage approving body and/or environmental regulator) and the 1:100 year greenfield allowable runoff rate reduced to take account of this extra discharge (Kellagher, 2002).

An alternative approach to managing the extra runoff volumes from extreme events separately from the main drainage system is to release all runoff (above the 1 year event) from the site at a maximum rate of 2 l/s/ha or Q_{BAR} , whichever is the higher value (or as agreed with the drainage approving body and/or environmental regulator). This avoids the need to undertake more detailed calculations and modelling.

Kellagher (2002) demonstrates that if discharges are not limited to less than 3 l/s/ha, the drainage system will generally not be effective at retaining sufficient water on the site to prevent an increase in flood risk in the receiving catchment. A discharge limit of 2 l/s/ha (or Q_{BAR} , which allows for higher discharge rates for specific soil types) has generally been accepted as an appropriate industry standard in the UK, unless alternative site or catchment specific limits are agreed based on local risk evaluation.

24.10.2 Greenfield sites: LTS volume estimation

A simple approach to the calculation of Long-Term Storage Volume is provided in Kellagher (2013) and set out in **Equation 24.10**. This approach uses a fixed percentage runoff for pervious surfaces defined by SPR.

The formula allows assumptions to be made as to whether some or all of the paved and pervious areas contribute runoff. The formula assumes that only 80% (ie the 0.8 coefficient in the equation) runoff occurs from paved areas, but 100% runoff can be assumed if it is felt that a more conservative assumption is needed. The pervious surfaces are assumed to have the same runoff coefficient before and after development. However, where sites are landscaped to prevent green areas contributing runoff or where pervious surfaces are likely to be heavily compacted following development, then adjustments to the coefficients can be made accordingly.

**EQ.
24.10**

Estimating the extra runoff volume from a development site compared to the greenfield equivalent

$$Vol_{xs} = RD \times A \times 10 \left[\frac{PIMP}{100} (\alpha 0.8) + \left(1 - \frac{PIMP}{100} \right) (\beta SPR) - SPR \right]$$

where:

- Vol_{xs} = extra runoff volume of development runoff over greenfield runoff (m³)
- RD = rainfall depth for the 1:100 year, 6 hour event (mm)
- $PIMP$ = impermeable area as a percentage of the total area
- A = area of the site, in hectares (ha)
- SPR = SPR index for the SOIL or HOST class (specified as a decimal proportion; this specifies the proportion of runoff from pervious surfaces (if SPRHOST values are used, then the minimum value should be set to 0.1)
- α = proportion of paved area draining to the network (values 0–1) with 80% assumed runoff
- β = proportion of the pervious area draining to the network or directly to the river (values from 0 to 1)

If the paved area is assumed to drain to the network, and all the permeable areas are landscaped so that they do not enter the drainage system or river, Equation 1 simplifies to:

$$Vol_{xs} = RD \times A \times 10 \left(0.8 \frac{PIMP}{100} - SPR \right)$$

However, where all the permeable areas are assumed to continue to drain to the river or network as well as all paved areas, Equation 2 becomes:

$$Vol_{xs} = RD \times A \times 10 (0.8 - SPR) \frac{PIMP}{100}$$

The ReFH2 software can also be used to estimate the development and greenfield site runoff hydrographs using a dynamic estimate of percentage runoff (reflecting the evolution of soil water content for pervious surfaces during the event) (CEH and WHS, 2015). These hydrographs can then be compared to determine the difference in runoff volume.

Figures 24.10 and 24.11 illustrate the difference in runoff volume for the two extremes: fully disconnected pervious areas and fully connected pervious areas for the five different soil types, for any development density. By multiplying the x axis value by the catchment area and the rainfall depth, a storage volume can be derived.

These graphs demonstrate the very great impacts of different soil types, the importance of using infiltration to disconnect impermeable areas from the drainage network, and the need to be efficient in designing the general landscape to disconnect pervious areas.

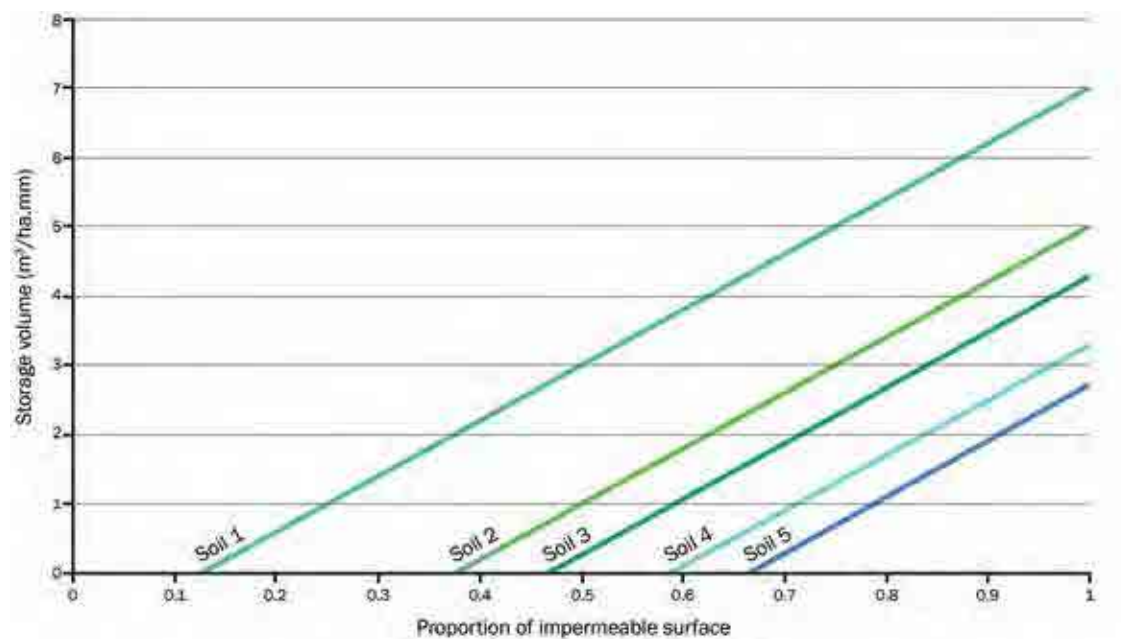


Figure 24.10 Difference in runoff volume for developments where all pervious areas are assumed not to drain to the drainage network

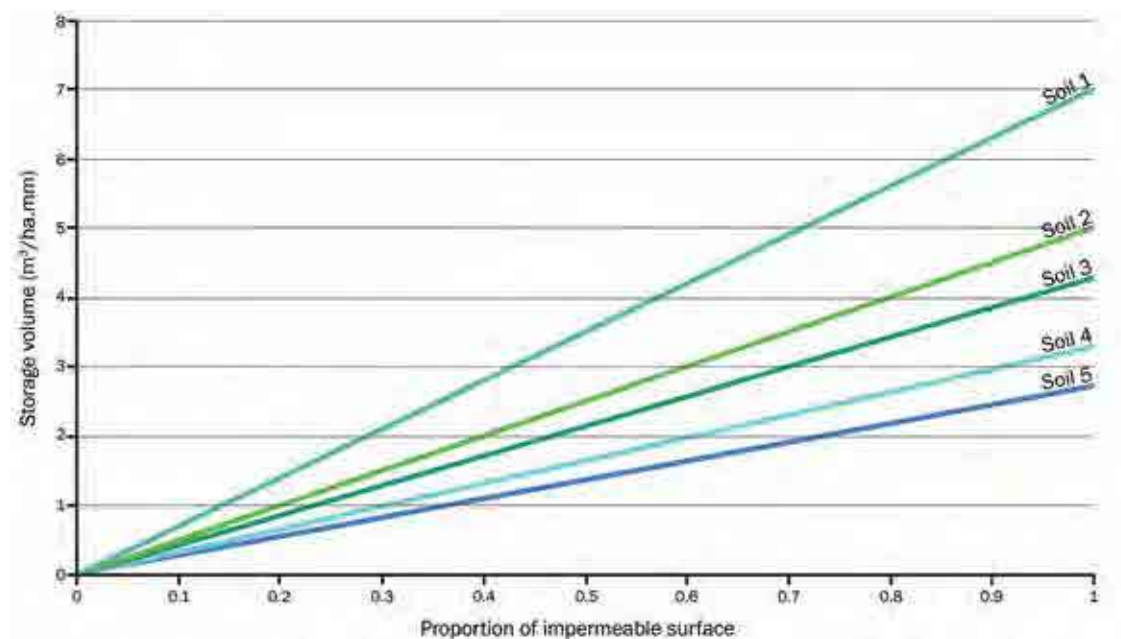


Figure 24.11 Difference in runoff volume for developments where all pervious areas are assumed to drain to the drainage network

24.10.3 Previously developed sites: LTS volume estimation

Where the environmental regulator or drainage approval body agrees that the runoff volume for a previously developed site can be constrained to the previously developed runoff volume (rather than greenfield), **Equation 24.11** can be used to determine the difference in runoff volume between the new and existing development scenario. The application of the equivalent approach within the ReFH2 software is described in the technical guidance document (CEH and WHS, 2015).

The use of this equation assumes that a positive drainage system can be demonstrated to be operational (**Section 24.5**).

EQ. 24.11 Estimating the extra runoff volume from a proposed development site compared to the previously developed site

$$Vol_{xs} = RD \times A \times 10 \left[(0.8 - SPR) \frac{PIMP_2}{100} + (SPR - 0.8) \frac{PIMP_1}{100} \right]$$

where:

- Vol_{xs} = extra runoff volume of the proposed development runoff over the runoff volume from the previously developed site (m³)
- RD = rainfall depth for the 1:100 year, 6 hour event (mm)
- A = area of the site (ha)
- SPR = SPR index for the SOIL or HOST class (specified as a decimal proportion); this specifies the proportion of runoff from pervious surfaces (if SPRHOST values are used, the minimum value should be set to 0.1)
- $PIMP_2$ = percentage impermeability of the proposed site
- $PIMP_1$ = percentage impermeability of the previously developed site

24.10.4 The practicalities of delivering volumetric runoff control

Any approach that delivers a reduction in the volume of runoff from the site will help in minimising the volume of storage that requires attenuation and slow release. Runoff reduction approaches include the use of vegetation to prevent runoff from indirectly drained areas, infiltration (both where infiltration rates are considered suitable for standard infiltration design – **Chapter 25**) and also where infiltration rates are poor, but some runoff reduction can be assumed (**Section 24.8**), and rainwater harvesting (where designed to deliver surface water management – **Chapter 11**).

Volumetric control only has to be met at the 1:100 year return period. Up until that point, events need only be constrained to the peak greenfield discharge rates. In practice, particularly where the Long-Term Storage Volume at 1:100 year is likely to be large, some form of spill or discharge control will need to come into effect at return periods of 1:5 years or 1:10 years, in order to ensure that the full volume is captured for the 1:100 year event.

In order to design a drainage system to minimise storage requirements (and, therefore, the space allocated to it and associated cost), consideration should be given to the feasibility of designing the normal attenuation storage units to overflow into the Long-Term Storage area when large events occur. This requires careful consideration of levels, but it does allow the off-line storage to be a multi-functional space – that is, it can have a primary function (eg car park, agriculture, recreation or amenity area) and will only be required infrequently for surface water management.

The critical duration event for the on-line attenuation system may be less than 6 hours, but more likely it will be much longer (eg around 24 hours). This means that the design needs to take account of two event durations: the critical duration for the attenuation storage system and the 6 hour event, which for the 1:100 year return period should meet the greenfield volume discharge criterion.

Any space that has another primary function should be designed with the frequency, depth, duration and velocity of flooding as key considerations. For example, in the case of temporary car park flooding, a

maximum depth of around 150 mm would probably be required to avoid damage to vehicles for any size of event. The allowable duration of flooding would be a function of what might be an acceptable level of risk and inconvenience. The impact of the effect of flooding (for instance, saturation of a football pitch for up to a week after the flooding occurs, or potential damaging effects of sediment on a pervious pavement) needs to be evaluated and mitigated. Local communities, site owners, operators and people who use or visit the area should understand the dual functionality of temporary flood storage areas.

Maintenance procedures should be put in place to ensure that the functionality of the area as a surface water management feature is never compromised and to rehabilitate the area following a flood. Effective emergency procedures should be put in place for when the area is likely to fill with water. The drain-down of the area may be by infiltration or by direct throttle control, but any solution should be practical and robust in coming into effect in a proper manner even though it only has to operate rarely. Where the discharge rate has to be very low, the outfall structure will need to be designed to reduce the risk of blockage.

24.11 CONVEYANCE DESIGN

The layout of the development site, particularly the roads and the drainage system, should be designed so that natural overland conveyance pathways are used to manage surface runoff, where appropriate. Modern developments often have terraced houses, and care over building orientation and position, landscape design and the creation of long barriers to floodwaters is needed to avoid increasing the risk of local flooding.

24.11.1 Surface conveyance systems

Surface conveyance systems, such as swales, channels and ditches, should be designed to convey the peak design flow rate. The return period normally specified is the 1:30 year event (ie this should be conveyed before overland flow is permitted), but this level of service might be either increased or reduced depending on the consequence of flooding at a location. Manning's formula can be used to check on the capacity of individual channels (**Equation 24.12**), but the easiest way of checking the system performance is to carry out hydraulic simulation modelling using Manning's or Colebrook–White equations.

Two-dimensional mesh models can be used to show the flow paths, depths and velocities across the site for the 1:100 year or larger events. As with channels, there is a need to use appropriate hydraulic roughness coefficients in the 2D models for the overland flows.

Note that as SuDS are both volumetric storage units and conveyance elements, flooding will occur at different points in the site for different selected storm durations.

EQ. 24.12 Manning's conveyance equation (from Chow, 1959)

$$Q = \frac{A R^{2/3} S^{1/2}}{n}$$

where:

- Q = flow rate (m^3/s)
- n = Manning's coefficient, a roughness coefficient dependent upon the channel characteristics ($\text{m}^{-1/3}\text{s}$)
- S = overall slope of the channel (m/m)
- R = hydraulic radius = A/P , where A is the cross-sectional area (m^2) and P is the wetted perimeter (m)

Values of Manning's coefficient "n" can be obtained from many standard text books. Recommended values for grass channels are presented in **Section 17.4**.

24.11.2 Pipe conveyance systems

Pipes are still likely to be required to provide some of the conveyance and drainage connectivity for a site. All pipe networks should conform to BS EN 752:2008, which specifies minimum pipe diameters and gradients. In general, pipes should be at least 150 mm in diameter, and these should not be laid on a slope that is flatter than 1 in 150. Where larger pipes are required, pipes can be laid at gradients using the inverse of the pipe diameter, so a 225 mm pipe can be laid at 1 in 225 or steeper and a 300 mm pipe at 1 in 300 or steeper. For pipes larger than 500 mm, gradients should not generally be flatter than 1 in 500 due to construction tolerances. Pipes and manufactured channel components should be sized to carry the maximum design event peak flow rate using product literature, pipe capacity tables or hydraulic simulation modelling. All pipe networks to be adopted should conform to the most up-to-date guidance from the relevant sewerage undertakers (at the time of publication these are WRc 2007, 2010 and 2012). Relevant building regulations should be referenced for specifications for drainage pipework serving single properties.

24.12 EXCEEDANCE DESIGN

Exceedance flow management on the site should be designed to mitigate the risks to people and property associated with:

- 1 rates of runoff exceeding the designed capacity of the drainage system (for both conveyance and storage components)
- 2 restrictions on outflows from the drainage system due to high levels in the receiving water body
- 3 system blockages or other failures.

Very high rainfall intensities can occur for short periods in the UK, and these can overwhelm pipe-based systems for brief periods. SuDS tend to have longer-duration critical events and can often absorb the impact of short thunderstorms much better than pipe-based systems, even though their return period may be high. However, in all cases, there will be events that cause flooding at points in the network if the event is severe enough and is of a relevant duration. The return period to use to evaluate these events is often limited to 1:100 years with a climate change factor. However, dam break risks, nuclear establishments or critical infrastructure all warrant evaluation of the impact of more severe (less frequent) events. The appropriate return period to use should be based on the implications of the consequence of such an event occurring. There are some sources of guidance on this, such as the application of the Reservoirs Act 1975 or the requirements of the nuclear industry, but in most cases this will be a matter for site specific determination.

Particular attention is needed on steep sites, due to focused flow paths and high velocities that might provide a scour risk or a hazard to people. Steep slopes also require attention in terms of modifying the runoff model, as saturated pervious areas can contribute rapid and high levels of runoff.

When the drainage system is overloaded, the surface water runs down to low points on the site. It is, therefore, important to consider this effect, and design the site layout and topography to adequately manage these flood risks. Although it is relatively easy to spot flood risk areas by examining the site contours and layout, the magnitude of flood ponding will be significantly influenced by the characteristics of the site and the drainage system. At the stage of initial evaluation, identifying the extent of flooding at these locations is difficult, as they can only be effectively determined using detailed simulation models.

Sites are particularly at risk during the construction period, as areas stripped of topsoil can act in a similar manner to paved surfaces and can generate very high rates of runoff, as well as contributing high levels of sediment and debris. This requires consideration when designing a temporary surface water management system and environmental protection during the construction phase, and when designing SuDS to manage scenarios where the development is being implemented in phases.

The design of exceedance flow management systems should therefore take account of:

- the location, use and capacity of exceedance flood pathways

- any low spots within the development that may act as temporary flood storage areas
- the location of properties and sensitive/critical infrastructure
- potential consequences of exceedance flows to people and/or property.

Surface flood conveyance paths or storage zones for extreme events should:

- 1 not detract from the primary function of the drainage system
- 2 be protected and maintained to ensure their continued availability as a flood management feature
- 3 include a freeboard allowance to allow for uncertainties
- 4 be designed so that flood depths and velocities are limited to acceptable levels both on site and downstream of it
- 5 not block pathways that the public would need to use to escape from flooded areas (usually only an issue associated with stream flooding or river floodplains).

Roads may be appropriate to use for storing flood water for brief periods of time on an infrequent basis, subject to their maximum traffic speed and designation. Roads should not be used to store water on a frequent basis or where the speed of the traffic is such that any stored water poses a potential accident risk.

Detail on designing for exceedance can be found in Digman *et al* (2006) and Digman *et al* (2014).

24.13 SURFACE WATER PUMPING STATION DESIGN

Where surface water management for the site cannot avoid the use of pumping, the pumping station should be designed in accordance with BS EN 752:2008. Where the pumping station is to be adopted by the sewerage undertaker, it should also be designed in accordance with WRc (2007, 2010 and 2012).

24.14 REFERENCES

- ATKINSON, K (1989) *An introduction to numerical analysis, second edition*, John Wiley & Sons, London, UK (ISBN: 978-0-47162-489-6)
- BOORMAN, D, HOLLIS, J and LILLY, A (1995) *Hydrology of soil types: a hydrologically-based classification of the soils of the United Kingdom*, Report 126, Institute of Hydrology, Wallingford, Oxon, UK
- CEH (1999) *Flood Estimation Handbook (FEH)*, Centre for Ecology and Hydrology, Wallingford, Oxon, UK (ISBN: 978-1-90669-800-3). Go to: <http://tinyurl.com/o8lslay>
- CEH and WHS (2015) *The Revitalised Flood Hydrograph Model ReFH. Technical guidance*, Centre for Ecology & Hydrology, Wallingford, UK. Go to: <http://tinyurl.com/o9hg9hl>
- CHOW, V T (1959) *Open-channel hydraulics*, McGraw-Hill, New York, USA (ISBN: 978-1-93284-618-8)
- DIGMAN, C, BALMFORTH, D, KELLAGHER, R and BUTLER, D (2006) *Designing for exceedance in urban drainage – good practice*, C635, CIRIA, London (ISBN: 978-0-86017-635-0). Go to: www.ciria.org
- DIGMAN, C, ASHLEY, R, HARGREAVES, P and GILL, E (2014) *Managing urban flooding from heavy rainfall – encouraging the uptake of designing for exceedance*, C738, CIRIA, London, UK (ISBN: 978-0-86017-742-5). Go to: www.ciria.org
- EA (2015) *Flood estimation guidelines. Operational instruction 197_08, version 5*, Environment Agency, Bristol, UK. Go to: http://persona.uk.com/A21Ton/Core_dox/H/H13.pdf

FAULKNER, D (1999) "Rainfall Frequency Estimation", *Flood Estimation Handbook, volume 2*, Institute of Hydrology, Wallingford, Oxon, UK (ISBN: 978-1-90669-800-3). Go to: <http://tinyurl.com/o8lslay>

FAULKNER, D, KJELDSEN, T, PACKMAN, J and STEWART, L (2012) *Estimating flood peaks and hydrographs for small catchments: Phase 1*, SC090031/R, Environment Agency, Bristol, UK. Go to: <http://tinyurl.com/p2l9eax>

HR WALLINGFORD (1981) *The Wallingford Procedure*, WP5, HR Wallingford, Oxon, UK. Go to: <http://tinyurl.com/o7azzx4>

KELLAGHER, R (2000) *Wallingford procedure for Europe: Best practice guide to urban drainage modelling*, WP6, HR Wallingford, Wallingford, Oxon, UK. Go to: <http://tinyurl.com/o7azzx4>

KELLAGHER, R (2002) *Storage requirements for rainfall runoff from greenfield development sites. Version 2*, SR580, HR Wallingford, Oxon, UK. Go to: <http://tinyurl.com/q22bolr>

KELLAGHER, R (2013) *Rainfall runoff management for developments*, Report SCS030219, Environment Agency, Bristol, UK (ISBN: 978-1-84911-309-0)

KJELDSEN, T (2007) *The revitalised FSR/FEH rainfall-runoff model*, Flood Estimation Handbook, Supplementary Report No. 1, Centre for Ecology & Hydrology, Wallingford, Oxon, UK (ISBN: 0-90374-115-7). Go to: <http://tinyurl.com/oztkjgg>

KJELDSEN, T (2014) "How reliable are design flood estimates in the UK?" *Journal of Flood Risk Management*, vol 8, 3, Wiley Online, UK, pp 237–246

KJELDSEN, T, JONES, D and BAYLISS, A (2008) *Improving the FEH statistical procedures for flood frequency estimation*, Science Report SC050050, Environment Agency, Bristol, UK (ISBN: 978-1-84432-920-5). Go to: <http://tinyurl.com/nn6y2ad>

KJELDSEN, T, MILLER, J and PACKMAN, J (2013) "Modelling design flood hydrographs in catchments with mixed urban and rural land cover" *Hydrology Research*, vol 44, 6, IWA Publishing, London, UK, pp 1040–1057

MARGETTS, J (2002) "If the NAPI fits...". In: *WaPUG conference*, Coventry, 2002

MARSHALL, D and BAYLISS, A (1994) *Flood estimation for small catchments*, Report 124, Institute of Hydrology, Wallingford, Oxon, UK (ISBN: 0-94854-062-1). Go to: http://nora.nerc.ac.uk/7367/1/IH_124.pdf

MAY, R and KELLAGHER, R (2004) *Drainage of development sites – a guide*, X108, CIRIA, London (ISBN: 978-0-86017-900-9). Go to: www.ciria.org

NERC (1975) *Flood Studies Report (FSR)*, Natural Environment Research Council, London, UK

NERC (1977) *The estimation of low return period floods*, Flood Studies Supplementary Report (FSSR) No. 2, Institute of Hydrology, Wallingford, Oxon, UK

NERC (1985) *The FSR rainfall–runoff model parameter estimation equations updated*, Flood Studies Supplementary Report (FSSR) No 16, Institute of Hydrology, Wallingford, Oxon, UK

NERC (1993) *Regional growth curves reviewed*, Flood Studies Supplementary Report (FSSR) No 14, Natural Environment Research Council, Swindon, UK

OSBORNE, M (2009) *A new runoff volume model*, WaPUG User Note No. 28, Chartered Institution of Water and Environmental Management, London, UK. Go to: <http://tinyurl.com/nv27kak>

OSBORNE, M (2012) "Design storms – have we been getting it wrong all this time?" In: *Proc WaPUG spring conference 2012*, Midlands Engineering Centre, Birmingham, 23 May 2012, Chartered Institution of Water and Environmental Management, London, UK. Go to: <http://tinyurl.com/oav6ccz>

PACKMAN, J C (1990) "New Hydrology model". In: *WaPUG conference*, Coventry, 10 June 1990

STEWART, E, JONES, D, SVENSSON, C, MORRIS, D, DEMPSEY, P, DENT, J, COLLIER, C AND ANDERSON, C (2013) *Reservoir safety – long return period rainfall*, R&D Technical Report WS 194/2/39/TR, Joint Defra/Environment Agency Flood and Coastal Erosion Risk Management Research & Development Programme, Department for Environment, Food and Rural Affairs, London. Go to: <http://tinyurl.com/osv9rag>

UKWIR (2014) *Development of the UKWIR runoff model: Main report*, 14/SW/01/6, UK Water Industry Research, London (ISBN: 1-84057-722-3)

WRc (2007) *Sewers for Scotland, second edition*, WRc Publications, Swindon, UK (ISBN: 978-1-89892-060-1)

WRc (2010) *Sewers for adoption Northern Ireland, first edition*, WRc Publications, Swindon, UK (ISBN: 978-1-89892-066-3)

WRc (2012) *Sewers for adoption, seventh edition*, WRc Publications, Swindon, UK (ISBN: 978-1-89892-065-6)

STATUTES

Acts

Reservoirs Act 1975 (c.23)

British Standards

BS 8515:2009+A1:2013 *Rainwater harvesting systems. Code of practice*

BS EN 752:2008 *Drain and sewer systems outside buildings*

Assessing attenuation storage volumes for SuDS



Anthony McCloy outlines the approaches to providing SuDS attenuation volumes, and highlights some important considerations when approaching attenuation designs or evaluations.

The author

Anthony McCloy, Managing Director of McCloy Consulting, is a Chartered Civil Engineer with expertise in water, hydrology, flood risk assessment and SuDS design. His experience to date includes analysis of drainage systems using various hydraulic modelling packages and development of guidance for Local Authorities.

As a leading specialist in the field of sustainable drainage, Anthony has been a key tutor for the (CIRIA) National SUDS training workshops since 2006 and resides on the Project Advisory Group for the SuDS Manual update.

Introduction

Flooding is a primary concern across many parts of the UK and Ireland. Whenever catchment flows exceed the capacity of the receiving watercourse, the excess water is conveyed or stored in the floodplain. Whenever a site is developed the rate of runoff from the site significantly increases. In order to protect the floodplain we endeavour to control runoff rates from a development to match that of predevelopment (Greenfield runoff) rates. Attenuation storage is required to hold back this volume of water to the required rate.

However, as we cover a development site with hard surfaces we also lose the potential for water to percolate into the ground.

As a floodplain has a finite volume, we mitigate by holding back the additional volume of runoff until floodwaters have abated. The retention of this additional volume of runoff for a longer period of time is generally referred to by the industry as Long Term Storage.

The process of how attenuation storage volumes are derived is generally not well understood across the various disciplines who are involved in the design of SuDS schemes. Many of us rely on spreadsheets, modelling software, published maps and charts or a helpful colleague to provide us with the volumes and flow we require to facilitate our SuDS design.

To deliver well considered and designed schemes it is important that all disciplines, not just hydraulic modelling specialists, have a broader appreciation of the attenuation calculation process, if only to ensure they can act as an intelligent client, or ask the right questions.

This fact sheet does not seek to rewrite hydraulic manuals. However, a number of aspects relating to the estimation of flows and volumes for SuDS design have been considered from a less-technical perspective than found in manuals. It is hoped that this information will be understandable to a wider range of members of the SuDS design / SuDS Approval Body (SAB) evaluation team. It should also provide the SAB team with an increased understanding to assist with the

assessment of uncomplicated schemes and identify when they may need to seek further advice from specialists.

The fact sheet covers the following aspects of attenuation design:

- Understanding fundamentals
- Making allowance for interception losses
- Selecting an appropriate Coefficient of volumetric runoff (C_v)
- Expressing attenuation storage volumes as m^3 for each m^2 of developed site area
- Approaches to determining storage volumes

Understanding the fundamentals of attenuation storage design

Prior to undertaking storage calculations it is important to understand a few of the basics of attenuation design. A few pointers are noted as follows:

- ✓ Water flows downhill! Levels of the site are vital and will be affected by approaches to managing volumes of water on the surface of the site.
- ✓ For flow rates to be attenuated / regulated, a flow control structure is required. This control could be an orifice, a weir or a more complex vortex flow control arrangement.
- ✓ It's likely to be more cost effective to store volumes of water across the site within each sub catchment as part of the SuDS management train, thus maximising the site potential, than storing at one location prior to discharge. Consequently, a number of flow controls are required to control flows and provide storage volumes along the management train.
- ✓ Anyone designing or evaluating attenuation volumes should know what 'ball park' volumes to expect prior to the calculation (or evaluation). This ensures that gross errors or model stability issues can be easily identified.
- ✓ If and when the specified design criteria for flows and volumes are exceeded,

attenuation storage will overtop. Similarly, storage will not perform to design standards if any part of the system becomes blocked. Designing for exceedance or blockage is as, if not more, important as determination of exact storage volumes.

- ✓ SuDS are designed to mimic natural drainage processes; therefore an understanding of natural drainage processes should be fully appreciated by the designer.
- ✓ Don't overlook the linkage between stored volumes of water and the other aspects of SuDS such as water quality and amenity benefit. Storage volume areas should be multi-functional and should be at or near the surface wherever possible.

Don't expect exact answers from the calculation process, it is a usable approximation that can provide acceptable solutions for design. Most of the inputs are based on statistics and calibration factors; therefore we can only ever achieve an approximation of how the system will behave in reality. The results of calculations and modelling need to be used alongside professional judgement to provide the design.

Interception losses

It is generally considered that about 50% of each year's total rainfall occurs in events which are less than 5mm in depth. In a natural catchment, the first 4mm to 5mm of rainfall is lost due to natural processes such as soakage into the topsoil, infiltration, evaporation and transpiration (combined this is referred to as evapotranspiration); and therefore does not result in runoff. Source control techniques such as green roofs, permeable pavements and swales can be provided to replicate natural catchment processes.

www.UKSuDS.com provides a Storage evaluation tool which can provide estimates for flows and volumes.

In calculation terms, where Source Controls are provided, an allowance can be made for interception losses by reducing rainfall depths by 5mm when deriving runoff generated (i.e. inflow to the attenuation storage calculation).

Selecting and appropriate coefficient of volumetric runoff (Cv)

The specification of a runoff coefficient attempts to represent the volume of flow from a particular surface. For example, in most circumstances you would anticipate less runoff from a grassed surface when compared to an impermeable road or roof surface. This is represented through the definition of Cv, with values ranging from 0% (no runoff from rainfall) up to 100% (all of the rainfall that occurs on a surface occurs as runoff).

The 'standard defaults' for the Coefficient of Volumetric Runoff (suggested by Modified Rational Method) consider that a proportion of sub-catchment contributing runoff to the drainage system is permeable. The Modified Rational Method guidance coefficients are 0.75 for summer and 0.84 for winter scenarios. This assumes that permeable parts of the sub-catchment will be wetter in winter and therefore produce more runoff.

However, the majority of attenuation volume calculations consider impermeable areas only as contributing to the drainage system. Therefore careful consideration needs to be given to the specification of Cv, as the default values used in software packages may not be appropriate.

Sewers for Adoption (7th Edition) recommends that a Cv of 1.0 should be used whenever calculating runoff from impermeable surfaces (*roofs and paved areas should have an impermeability of 100%*). When making an application the designer should demonstrate to the SAB that Cv has been suitably determined.

Sub-catchments and providing attenuation storage in various locations across the site

Attenuation storage volumes are generally expressed as a single volume for the entire site. Intuitively this has led to storage been allocated to a single location, i.e. site control. However, to develop SuDS schemes which are affordable and maximise the opportunity of the site, storage should be allocated across the site within each sub-catchment. To aid design an updated approach is required to express storage volumes

By expressing attenuation volumes in terms of 'm³' for each 'm²' of developed area, allows a much more flexible approach to allocating storage across the site rather than at a single location.

For example if 1 hectare of developed site area was calculated to require 700m³ of attenuation storage. Then, for each **1 m²** of developed area we would provide = 0.07m³, or 70 litres, or **70mm depth of storage**

This change in approach, in terms of how the attenuation volumes are expressed allows for;

- easy allocation of storage to each sub-catchment as part of design
- allows more flexibility during design iterations without the requirement to remodel the entire system to calculate a new volume after each design iteration
- a more transparent figure for evaluation by the SAB.

The attenuation volume on a m³/m² basis can be deduced by dividing the calculated attenuation volume by the developed area of the site (Roof areas + roads areas + any other hard standing surface)

There are numerous benefits from allocating storage at source, which include;

- Making maximum opportunity of the storage available on the site through the use of existing landscape and permeable hard surfaces without the requirement of land to be used solely for storage of flow (generally located prior to the final discharge point from the site)
- The attenuation volume requirement for the site control is proportionally reduced
- Conveyance requirements are greatly reduced
- Greatly reduces risk of erosion as flow rates are significantly reduced
- Opportunity to provide water quality treatment (if appropriately designed)

Determining attenuation storage volumes

The SuDS Manual sets out two approaches for managing flows and volumes from a development site.

The 1st approach (**Approach 1**) requires that flows rates discharged from the site attenuation storage are controlled at a rate equivalent to the runoff from a Greenfield site for a 1 in 1 year return period (whenever a 1 in 1 year rainfall event occurs), up to the equivalent runoff from a Greenfield site for a 1 in 100 year return period (whenever a 1 in 100 year rainfall event occurs).

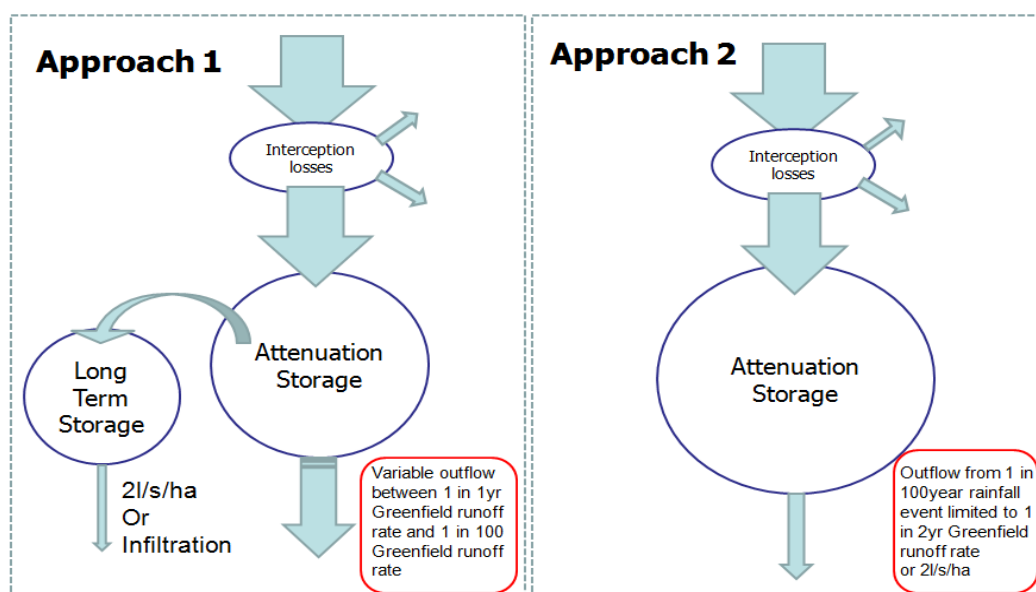
Greenfield runoff rates are generally 3-4 times greater for the 1 in 100 year rainfall event when compared to the 1 in 1 year rainfall event. To capitalise on the use of the 1 in 100 year Greenfield runoff allowance, **long term storage** must be provided; whereby a specified volume of water is held on site for a longer period in comparison to the attenuated storage volume.

The application and design of Long Term Storage will be described in a follow on Fact Sheet.

Provision of long term storage may not always be achievable, therefore a second approach has been devised which attains similar results in terms of protection of the floodplain.

The 2nd approach (**Approach 2**) requires that flows from the attenuation storage are controlled at 1 in 2 year Greenfield runoff rate, for all rainfall events up to and including the 1 in 100 year rainfall return period.

Figure 1 - Two approaches for managing flows and volumes from a development site



There are a few aspects to consider when determining which approach to adopt, outlined as follows:

- Can Long Term Storage be provided on the site to accommodate the additional volume of runoff generated.
- Approach 2 will generally result in a higher overall storage volume for the site.
- Approach 2 will have longer drain-down times, and it may be difficult to achieve 50% drain down within 24 hours. However the adoption of 24 hour half drain down times for design events of 1 in 100years plus allowances for climate change is questionable and a more considered approach may be reasonable (eg. ensuring that the drain down in 24 hours provides room for a subsequent 1 in 10 year event).

Summary

In summary, there are a number of important aspects to consider whenever approaching design or evaluation.

- Expressing volumes in an understandable format such as **m³ per m²** of developed site area, or mm depth per m², makes the approach to design more flexible and simplifies the evaluation process.
- Runoff coefficients need to be carefully considered whenever calculating runoff from impermeable surfaces. **Standard defaults may not always be appropriate.**
- Designing for **exceedance** or blockage is as important in design terms as defining attenuation storage volume. Design of outlets and flow control should ensure that they robust, not prone to blockage and have overflows to cover any failure.
- The calculated storage should replicate what is on the drawings and what is installed,
- Levels are vital! SABs should make specific drawing checks on levels and storage and continue to do so through the design and installation process.

It is important to remember that there are NO absolute answers in the estimation of storage volumes; however there are certain 'ball parks' that the calculated outcomes should be within. Any calculation, regardless how refined, can only ever be an approximation of the actual functioning of natural system; for example a SuDS management train which should perform like a natural system!

References

CIRIA (2004). **Sustainable drainage systems, hydraulic, structural and water quality advice**. CIRIA Report C609.

CIRIA (2007). **The SuDS Manual**. CIRIA Report C697.

Water UK / WRc plc (2012). **Sewers for Adoption** (7th Edition)

HR Wallingford. **www.UKsuds.com**

For further advice on designing SuDS schemes to incorporate attenuation storage in a practical cost effective way please contact Anthony McCloy - 02890 848694 or email anthony@mccloyconsulting.com

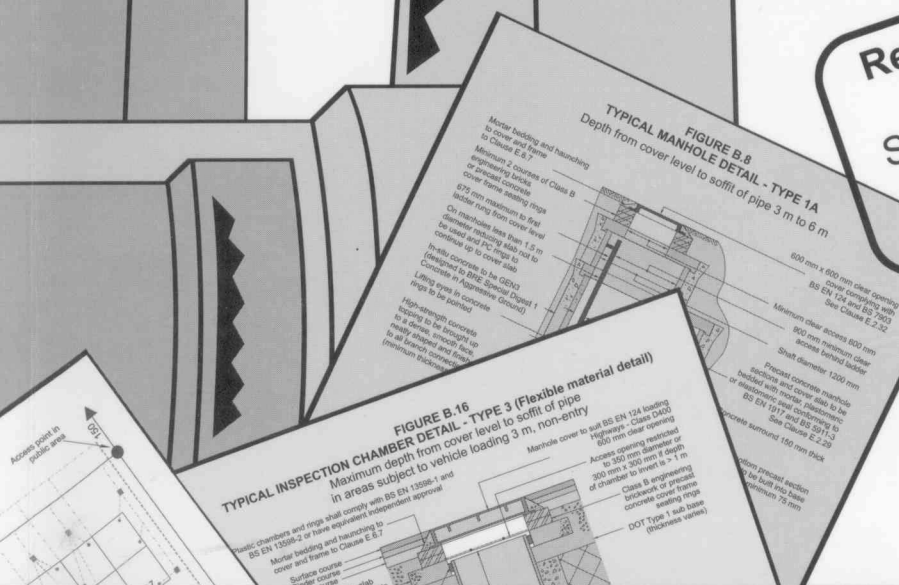
 **McCloy Consulting**
Water Engineering Solutions



7th Edition

A design and construction guide
for developers

Recommendation:
Talk to the
Sewerage Company
before applying
for Planning



WATER/UK

C5 HYDRAULIC DESIGN

C5.1 Surface Water on Site

1. An appropriate flow simulation method based on the Wallingford Procedure should be used for hydraulic design, unless otherwise agreed with the Undertaker, e.g., in the case of small developments.
2. The system should be designed under pipe full conditions to accept the following design storm (i.e., without surcharging above pipe soffit):
 - sites with average ground slopes greater than 1% 1 year;
 - sites with average ground slopes 1% or less 2 year; and
 - sites where consequences of flooding are severe 5 year.
(e.g., existing basement properties adjacent to new development)
3. Surface water sewers should be designed for runoff from roofs and, subject to the agreement of the Undertaker, highways (including verges) and other paved areas. For these areas, an impermeability of 100% should generally be assumed. They should not be designed to take runoff from other areas or land drainage. In these cases, satisfactory and separate arrangements should be agreed with the local Land Drainage Authority and confirmed to the Undertaker.
4. The roughness value (k_s) for surface water sewer design should be 0.6 mm.

C5.2 Protection Against Flooding

1. The system should be designed not to flood any part of the site in a 1:30 year return period design storm.
2. Any underground storage to be constructed to attenuate the 1:30 event should be sited within the system being offered for adoption. Where the Developer proposes to provide storage over and above the 1:30 year event, they should have early discussions with the Undertaker.
3. All sewers are designed to not flood in a 1:30 year event, but they will be surcharged. Therefore, when calculating the 1:30 year storage volume for the site, the Developer should consider the location of the storage tank for a free-flowing discharge.
4. During extremely wet weather, the capacity of the surface water sewers may be inadequate, even though they have been designed in accordance with Clause C5.2.2. Under such conditions, sewers may surcharge and surface water can escape from those manhole covers which lie below the hydraulic gradient. In designing the site sewerage and layout, Developers should also demonstrate flow paths and the potential effects of flooding resulting from extreme rainfall blockages, pumping station failure or surcharging in downstream sewers, by checking the ground levels around the likely points that flow would flood from the system to identify the flood routes.

Appendix A.11 – Email correspondence with Stantec, dated 7th August 2023

[REDACTED]

From: [REDACTED]
Sent: 07 August 2023 15:59
To: [REDACTED]
Cc: [REDACTED]g
Subject: Re: URGENT REQUEST - Inquiry Bird in Eye Farm - Inquiry Information

[REDACTED]

See responses below

1. A catchment plan was not prepared by Stantec as part of the FRA submitted in April 2021. Therefore, the only information provided to the LPA regarding the areas which were used to size the drainage system are the numbers included within the body of the FRA report and the appended modelling outputs.

Correct. The LLFA is satisfied with this approach.

2. Pre- and post-development rates are stated within table 6.1, however, only the Micro Drainage model outputs have been appended to the FRA for the 1 in 100 year rainfall event, including a 40% allowance for climate change. The Micro Drainage outputs for the other return periods stated within table 6.1 were not made available to the LPA and have not been provided as part of the submission (i.e. QBAR, 1 in 30, 1 in 100) or subsequent updates.

The MicroDrainage model output is to determine the maximum storage volume of the proposed detention basin. Runoff rates have been calculated using FEH post-2008 Statistical Method as MicroDrainage uses the pre-2008 method. The rates quotes in Table 6.1 demonstrate the compliance criteria for a future Reserved Matters application where a network model would be generated, as is typical.

3. It was agreed between Stantec and the LLFA that all areas upstream of the swales were to be considered in the impermeable area calculation, as they could potentially drain to the basin. It is unclear whether this includes the existing farm (blue line boundary). **Please you could confirm whether the farm was included or excluded from the calculations, as it is unclear from reading the report?**

All areas upstream of the swales within the proposed application boundary, which has been confirmed as satisfactory to the LLFA. The existing farm buildings are not within the application boundary and therefore excluded

4. Areas downstream of the swales and basin are not included in the impermeable areas, due to their inability to contribute flows to the surface water drainage strategy.

Correct, their existing hydrological regime will remain

5. No further modelling was undertaken when the drainage report was updated in January 2023, as Stantec is of the opinion that no further modelling was necessary, as it is only the outfall location that was updated in the latest iteration.

Correct. We have since undertaken a sensitivity test of the detention basin to account for climate change guidance which was updated post-submission. This will be available in our proof of evidence.

6. CV values were not calculated as the LLFA agreed that a source control design with Micro Drainage would be sufficient without modelling the entire network, as detailed in the minutes of the meeting with ESCC as LLFA on 05/05/2020 (minutes in Appendix F of FRA Rev C April 2021).

Correct. The LLFA is satisfied which this approach.

I am sure you have seen but the LLFA has confirmed they have no objection subject to condition based on our outfall route to the north of the ancient woodland

Finally - a previous email from you referenced a roundabout. The roundabout was considered briefly as an option related to a bus service entering and turning within the northern part of the site. This is no longer proposed and therefore it has not been considered within the drainage strategy

I trust this answers all your queries

Sent from [Outlook for iOS](#)

From: [REDACTED]
Sent: Friday, August 4, 2023 4:26:56 PM
To: [REDACTED]
Cc: [REDACTED]
Subject: RE: URGENT REQUEST - Inquiry Bird in Eye Farm - Inquiry Information

Dear Amy,

Thank you for your email reply and for confirming what information has previously been submitted, which appears to be congruent with the documentation that has been uploaded to the planning portal.

To ensure I have understood correctly, I have summarised the key points below, but please feel free to come back to me if I have misunderstood for any reason;

1. A catchment plan was not prepared by Stantec as part of the FRA submitted in April 2021. Therefore, the only information provided to the LPA regarding the areas which were used to size the drainage system are the numbers included within the body of the FRA report and the appended modelling outputs.
2. Pre- and post-development rates are stated within table 6.1, however, only the Micro Drainage model outputs have been appended to the FRA for the 1 in 100 year rainfall event, including a 40% allowance for climate change. The Micro Drainage outputs for the other return periods stated within table 6.1 were not made available to the LPA and have not been provided as part of the submission (i.e. QBAR, 1 in 30, 1 in 100) or subsequent updates.
3. It was agreed between Stantec and the LLFA that all areas upstream of the swales were to be considered in the impermeable area calculation, as they could potentially drain to the basin. It is unclear whether this includes the existing farm (blue line boundary). **Please you could confirm whether the farm was included or excluded from the calculations, as it is unclear from reading the report?**
4. Areas downstream of the swales and basin are not included in the impermeable areas, due to their inability to contribute flows to the surface water drainage strategy.
5. No further modelling was undertaken when the drainage report was updated in January 2023, as Stantec is of the opinion that no further modelling was necessary, as it is only the outfall location that was updated in the latest iteration.
6. CV values were not calculated as the LLFA agreed that a source control design with Micro Drainage would be sufficient without modelling the entire network, as detailed in the minutes of the meeting with ESCC as LLFA on 05/05/2020 (minutes in Appendix F of FRA Rev C April 2021).

Thank you for clarifying and I would be grateful if you could confirm point 3 to ensure we are on the same page.

Kind regards

Canterbury | London | Cambridge | Bristol | Leeds

This email and any attachments with it are confidential and intended solely for the use of the individual or entity to whom they are addressed. If you received this message in error, or are not the intended recipient, you are prohibited from retaining, distributing, disclosing, copying or using information contained herein. Please inform the sender by return e-mail if you have received this e-mail in error and delete it from your system. Thank you for your cooperation. E-mail transmission cannot be guaranteed to be secure or error-free and the sender therefore does not accept liability for any errors in the contents of this message, which may have arisen during the e-mail transmission process. Herrington Consulting is a limited company (reg no 05418977) registered in England & Wales. Registered address: 7b Caxton House, Broad Street, Cambourne, Cambridge, CB23 6JN

From: [REDACTED]
Sent: Thursday, August 3, 2023 10:10 PM
To: [REDACTED]
Cc: [REDACTED]
Subject: RE: URGENT REQUEST - Inquiry Bird in Eye Farm - Inquiry Information

Attached is our 2021 FRA with full appendices

Pre- and post-development runoff rates are outlined in Table 6.1 (page 19) of FRA Rev C (April 2021). Any assumptions are described in paragraphs 6.3.1 to 6.3.6 (page 19) of the same report. The calculation of pre-development runoff rates, which as stated in Table 6.1 (page 19) are to be maintained post-development, can be found in Appendix F.

A catchment plan has not been prepared in support of these documents. However, in a meeting with ESCC as LLFA on 05/05/2020 (minutes in Appendix F of FRA Rev C April 2021) it was agreed that all areas upstream of the swales are considered in the impermeable area calculation as they could potentially drain to the detention basin, whilst areas downstream are not included due to their inability to contribute flows to the surface water drainage strategy.

MicroDrainage Source Control model results for the FRA Rev C (April 2021) are contained within Appendix F, which further discussion of these results in paragraph 7.3.12 (page 25). This approach was confirmed as acceptable by ESCC as LLFA in a meeting on 05/05/2020, the minutes of which are in Appendix F. The January 2023 drainage strategy is as 2021 with a change to the outfall route downstream of the flow control only. No new modelling was necessary.

CV values not calculated as no network model produced, based on modelling approach agreed as acceptable by ESCC as LLFA in a meeting on 05/05/2020, the minutes of which are in Appendix F.

I trust that gives you the information you requested

[REDACTED]
Caversham Bridge House, Waterman Place, Reading RG1 8DN
Direct: [REDACTED]
Mobile: [REDACTED]
amy.hensler@stantec.com



From: [REDACTED]
Sent: Thursday, August 3, 2023 6:43 PM
To: [REDACTED]
Cc: [REDACTED]
Subject: RE: URGENT REQUEST - Inquiry Bird in Eye Farm - Inquiry Information

Dear [REDACTED],

Regarding the relevance of my request, any appendices to your FRA and subsequent reports should be in the public domain and we are entitled to see them, but the Council does not appear to have uploaded these documents onto their website.

We are looking to satisfy ourselves that the drainage (SuDS) basin is properly sized and will work as stated, which you will be aware from our Statement of Case (as outlined at point 3.5 in our SoC). If we have access to your calculations, we will be able to satisfy ourselves that the work in FRA was robust in this respect and no doubt you will be dealing with the potential effects of scheme changes (i.e. roundabouts) in your evidence.

We shall draw these emails to the inspector's attention should you fail to provide us with your FRA appendices.

Kind regards

[REDACTED]

[REDACTED]

T: [REDACTED]



Canterbury | London | Cambridge | Bristol | Leeds

This email and any attachments with it are confidential and intended solely for the use of the individual or entity to whom they are addressed. If you received this message in error, or are not the intended recipient, you are prohibited from retaining, distributing, disclosing, copying or using information contained herein. Please inform the sender by return e-mail if you have received this e-mail in error and delete it from your system. Thank you for your cooperation. E-mail transmission cannot be guaranteed to be secure or error-free and the sender therefore does not accept liability for any errors in the contents of this message, which may have arisen during the e-mail transmission process. Herrington Consulting is a limited company (reg no 05418977) registered in England & Wales. Registered address: 7b Caxton House, Broad Street, Cambourne, Cambridge, CB23 6JN

From: [REDACTED] >
Sent: Thursday, August 3, 2023 5:02 PM
To: [REDACTED]
Cc: [REDACTED]
Subject: RE: URGENT REQUEST - Inquiry Bird in Eye Farm - Inquiry Information

Hi [REDACTED]

My out of office is on and I am on leave, but I also have a Proof to finalise and a SOCG to progress, so I am working.

Can you (or your solicitor) explain how the requests are relevant to the points which reflect their case as set out in the statement of case?



Caversham Bridge House, Waterman Place, Reading RG1 8DN

Direct:

Mobile:

amy.hensler@stantec.com



The content of this email is the confidential property of Stantec and should not be copied, modified, retransmitted, or used for any purpose except with Stantec's written authorization. If you are not the intended recipient, please delete all copies and notify us immediately.

Please consider the environment before printing this email.

From: [REDACTED]
Sent: Thursday, August 3, 2023 4:54 PM
To: [REDACTED]
Cc: [REDACTED]
Subject: RE: URGENT REQUEST - Inquiry Bird in Eye Farm - Inquiry Information

Dear [REDACTED],

I have just come back to my PC and received your out-of-office, saying you are on annual leave from tomorrow. Is my request something one of your colleagues could deal with in my absence and forward the relevant information.

Sorry to request this before you go away, however, as you will appreciate that this information is critical for us to establish whether the drainage strategy functions as designed.

Kind regards

[REDACTED]

[REDACTED]

T: [REDACTED] | E: [REDACTED]



Canterbury | London | Cambridge | Bristol | Leeds

This email and any attachments with it are confidential and intended solely for the use of the individual or entity to whom they are addressed. If you received this message in error, or are not the intended recipient, you are prohibited from retaining, distributing, disclosing, copying or using information contained herein. Please inform the sender by return e-mail if you have received this e-mail in error and delete it from your system. Thank you for your cooperation. E-mail transmission cannot be guaranteed to be secure or error-free and the sender therefore does not accept liability for any errors in the contents of this message, which may have arisen during the e-mail transmission process. Herrington Consulting is a limited company (reg no 05418977) registered in England & Wales. Registered address: 7b Caxton House, Broad Street, Cambourne, Cambridge, CB23 6JN

From: Hensler, Amy <amy.hensler@stantec.com>
Sent: Thursday, August 3, 2023 3:27 PM

To: Simon Maiden-Brooks <simon.mb@herringtonconsulting.co.uk>

Subject: Automatic reply: URGENT REQUEST - Inquiry Bird in Eye Farm - Inquiry Information

I am on leave from 4th August, returning on 14th, and only be checking emails intermittently

Disclaimer: The content of this email is the confidential property of Stantec and should not be copied, modified, retransmitted, or used for any purpose except with Stantec's written authorization. If you are not the intended recipient, please delete all copies and notify us immediately. This communication may come from a variety of legal entities within or associated with the Stantec group. For a full list of details for these entities please see our website at www.stantec.com. Where business communications relate to the Stantec UK Limited entity, the registered office is Kingsmead Business Park, London Road, High Wycombe, Buckinghamshire HP11 1JU Tel: 01494 526240 and the company is registered in England as registration number 01188070.

From: [REDACTED]
Sent: Thursday, August 3, 2023 11:36 AM
To: [REDACTED]
Cc: [REDACTED]
Subject: URGENT REQUEST - Inquiry Bird in Eye Farm - Inquiry Information
Importance: High

[REDACTED]er – Please re-direct this to the relevant person.

Dear [REDACTED], (or to whom it may concern)

Herrington Consulting Ltd. is currently in the process of reviewing the information in relation to the planning Inquiry for the application at Bird in Eye Farm, Uckfield (Appeal reference: APP/C1435/W/22/3307820), to be held on 12 September 2023.

We understand that Stantec are acting for the Appellant, having prepared the original Flood Risk Assessment in April 2021 and the subsequent drainage strategy update reports (January 2022 and January 2023 respectively).

The original Author of the April 2021 FRA (RevC - attached) is listed as Lewis Derrick, sign-off by [REDACTED] i (Director Water and Environment). The author of the January 2023 Stantec Technical Note (attached), is [REDACTED] (Director of Flood Risk at Stantec UK).

The reason for my email is to request some further information that is not included within the original FRA/Drainage strategy or subsequent drainage documentation submitted.

To ensure we can provide the Inspector with a true and unbiased view regarding the technical work that has been completed by Stantec, please would it be possible to provide me with the following information no later close of business than Monday 7th August 2023. This is to allow sufficient time for a review of the information to be completed:

1. Full calculations for the pre- and post-development with respect to run-off rates, including a description of any assumptions that have been made.
2. A catchment plan showing the areas draining to the proposed drainage system, pre- and post-development.
3. Micro-Drainage results for the following return period events; 1:2, 1:10, 1:30, 1:100, and 1:100+CC.

- Please can you provide the hydraulic model results (Micro Drainage) relating to the original FRA/drainage strategy submission (2021)
 - Please can you provide the hydraulic model results (Micro Drainage) for the latest revised drainage strategy submitted in January 2023.
4. A copy of the hydrological data (FEH point descriptors) that have been applied.
 5. Hydrological justification for your chosen SPR and how the impermeable area draining to the system has been calculated (what assumptions if any have been made?).
 6. Hydrological justification for any changes to FEH, or other, parameters used within any of your calculations.
 7. Any calculations undertaken to determine CV values within the proposed model.

I expect that the majority, if not all of the information requested above has already been prepared as part of the previous submissions, but not uploaded to the planning system. Therefore, it should simply be a case of forwarding the documentation requested, rather than having to produce this information.

If for any reason this information cannot be provided, I would kindly request that you contact me at your earliest opportunity.

Thank you in advance.

Kind regards

Simon

[REDACTED] M

T: [REDACTED] | E: [REDACTED]



Canterbury | London | Cambridge | Bristol | Leeds

This email and any attachments with it are confidential and intended solely for the use of the individual or entity to whom they are addressed. If you received this message in error, or are not the intended recipient, you are prohibited from retaining, distributing, disclosing, copying or using information contained herein. Please inform the sender by return e-mail if you have received this e-mail in error and delete it from your system. Thank you for your cooperation. E-mail transmission cannot be guaranteed to be secure or error-free and the sender therefore does not accept liability for any errors in the contents of this message, which may have arisen during the e-mail transmission process. Herrington Consulting is a limited company (reg no 05418977) registered in England & Wales. Registered address: 7b Caxton House, Broad Street, Cambourne, Cambridge, CB23 6JN

Caution: This email originated from outside of Stantec. Please take extra precaution.

Attention: Ce courriel provient de l'extérieur de Stantec. Veuillez prendre des précautions supplémentaires.

Atención: Este correo electrónico proviene de fuera de Stantec. Por favor, tome precauciones adicionales.

Disclaimer: The content of this email is the confidential property of Stantec and should not be copied, modified, retransmitted, or used for any purpose except with Stantec's written authorization. If you are not the intended recipient, please delete all copies and notify us immediately. This communication may come from a variety of legal entities within or associated with the Stantec group. For a full list of details for these entities please see our website at www.stantec.com. Where business communications relate to the Stantec UK Limited entity, the registered office is Kingsmead Business Park, London Road, High Wycombe, Buckinghamshire HP11 1JU Tel: 01494 526240 and the company is registered in England as registration number 01188070.