

Julia Edwards,
Corylus Planning & Environmental Ltd,
The Old Dairy,
Yanworth,
Cheltenham,
Glos. GL54 3LQ

Re: K0457

9th April 2014

Dear Julia,

FLOOD CONSEQUENCE ASSESSMENT: SOLAR FARM NEAR WREXHAM, LL14 4HY

This letter constitutes a Flood Consequence Assessment, for development of a proposed *circa* 3 mw photovoltaic array on land at Legacy, Bronwylfa Rd, near Wrexham. The main findings are summarised in this covering letter.

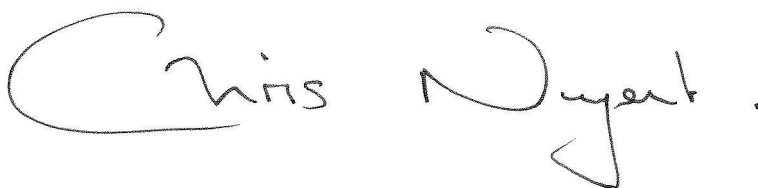
The site of proposed development is currently agricultural land. On Natural Resources Wales flood zone mapping, the site is shown to lie outside Flood Zone C, beyond the limit of the 1:1,000 year fluvial event. Geological mapping shows no alluvial deposits on the site, which is therefore taken to be entirely within Flood Zone A, so the Justification Test is not required.

The Preliminary Flood Risk Assessment for this area has no record of flooding from any source but Natural Resources Wales' surface flooding maps show a low to moderate risk of surface water flooding, along or parallel with existing streams which cross the site. These occupy a relatively small part of the site and represent, at most, an annual risk of up to 3.3% AEP, equivalent to the 1:30 year flood. Since the solar panels and associated infrastructure is able to survive brief periods of inundation and people would not be required to access the site during flooding, flood risk at the site is regarded as very small.

It is not anticipated that the proposed development will lead to any increase in flood risk downstream, since the proposed layout provides ample opportunity for local infiltration of any runoff from the solar panels. However, in order to mitigate any possible downstream effect, it is recommended that a series of swales are created across the site to detain runoff and give it an opportunity to infiltrate into the soil. Conservative assumptions were used to calculate the dimensions of such swales, which would be able to manage the 1:100 year rain storm, with an allowance for climate change. If conditions are less severe than assumed in this analysis, then downstream flood risk could be reduced by the development.

In summary, the risk of flooding at this site is small and surface water runoff can be managed to ensure that the development does not increase flood risk elsewhere. If the recommendations within this report are implemented, the proposed development would comply with TAN15.

Yours sincerely,



Chris Nugent
Senior Hydrologist



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1 Development description and location

1a. What type of development is proposed and where will it be located?

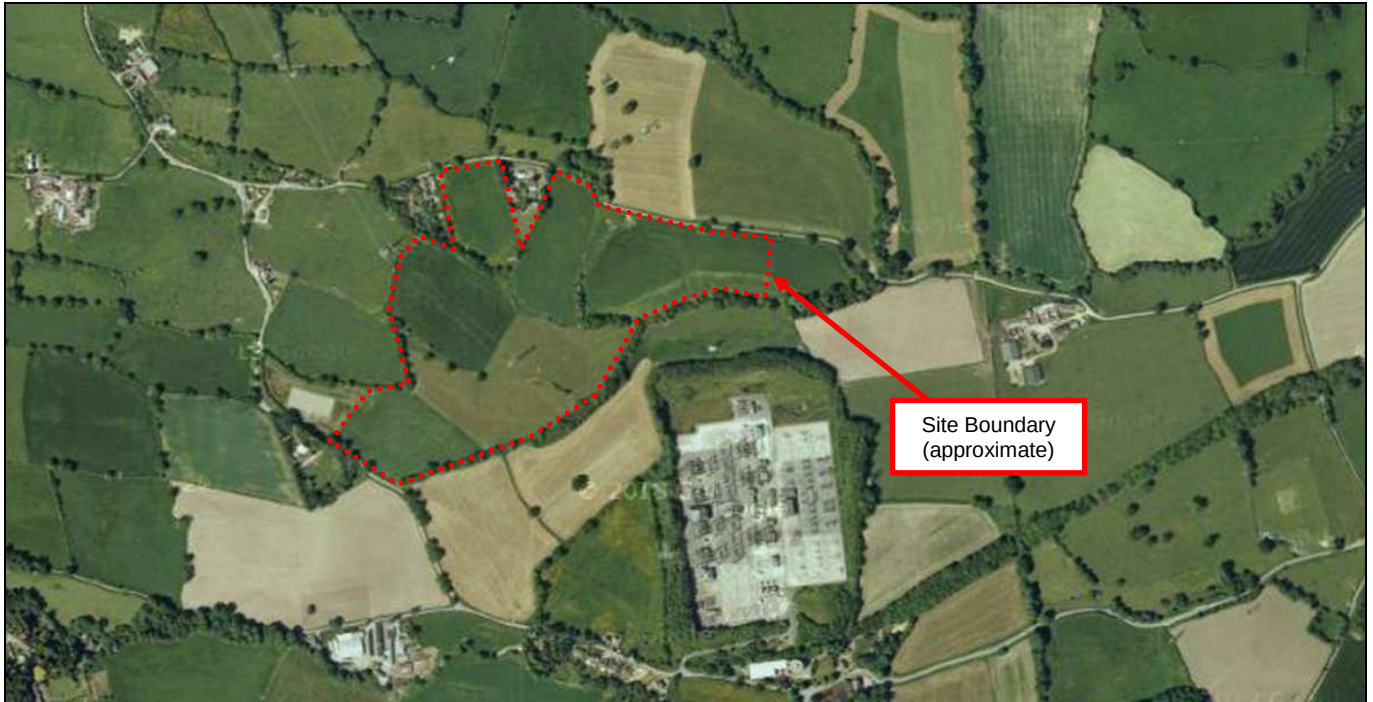
- A location plan should be provided at an appropriate scale.

It is proposed that a circa 3 mw photovoltaic array should be established on land at Legacy, Bronwylfa Rd, near Wrexham, LL14 4HY, as located in Figure 1. The site has most recently had an agriculture use, as shown by the air photo (Figure 2). The site lies to the north of a tributary of the River Dee and is crossed by two smaller streams.

Figure 1 Map showing the site location in relation to drainage and other features



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Figure 2 Air photo showing the site and bounding area

Source: Google Maps

1b. What is its development category?

- Development categories are provided in Figure 2 of TAN15

Power stations are classed as “Highly Vulnerable” under TAN15.

1c. Is the proposed development consistent with the Local Development Documents?

At the time of writing, the Wrexham County Borough Council Local Development Plan is in preparation. This will be a long-term land use and development strategy and will replace the current adopted Unitary Development Plan (UDP), which is therefore still current.

Under the heading “Renewable Energy”, Wrexham County Borough Council UDP lists their Policy PS12 as follows:

“Proposals for the generation of energy from renewable sources will be supported provided that the wider environmental benefits are not outweighed by any detrimental impacts of the proposed development (including any electricity transmission facilities needed) on the landscape, public safety, and the local environment”.

Subject to the assessment of detrimental impacts, this policy suggests that the proposed development is consistent with the Local Development Documents.

1d. Please provide evidence that the Justification Test has been applied in the selection of this site for this development type?

- Evidence is required that the Justification Test has been used in allocating the land use proposed for the site, as outlined in Section 6 of TAN15.

The site is outside the limits of Fluvial Flood Zone C, beyond the limits of the 1:1,000 year fluvial flood. In terms of TAN15, it is therefore not necessary to apply the Justification Test or to consider fluvial flood risk further.

2. Definition of the flood hazard

2a. What sources of flooding could affect the site? (see Appendix 1E of TAN15).

- This may include hazards such as the sea, reservoirs or canals, which are remote from the site itself, but which have the potential to affect flood risk.

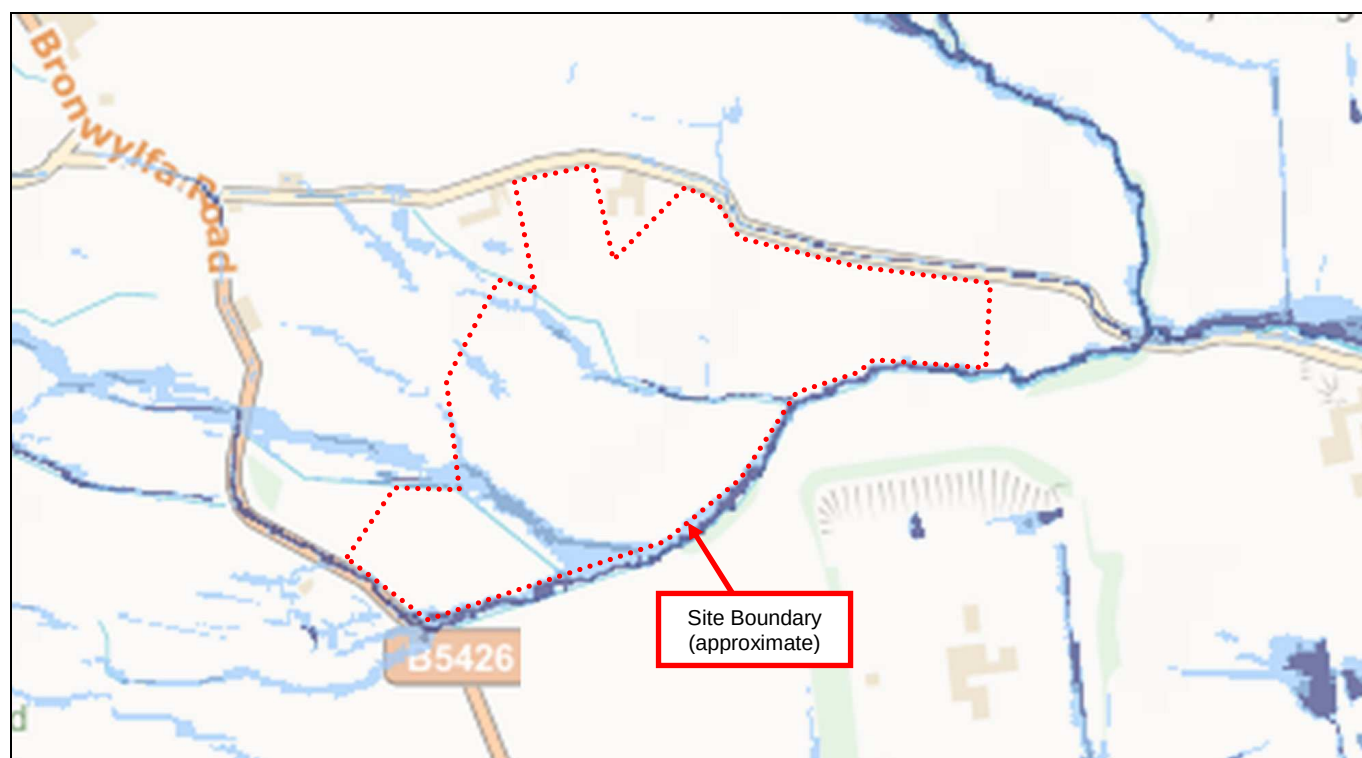
The risk of fluvial flooding is from small streams crossing the site and flowing along its southern border (Figure 1). These have narrow cross-sections and restricted floodplains, most of which lie within the 7 m standoff either side of the streams. The PFRA has no record of groundwater flooding anywhere in the Wrexham County Borough Council area (see Section 3b). The distribution of surface water flooding is shown in Figure 3 and is also considered in Section 2b.

Table 1 Sources of flooding which could affect the site

Key sources of flooding	Possibility at Site
Fluvial (Rivers)	Most or all of the site outside fluvial flood zone C
Tidal	N/A
Groundwater	None recorded in the area
Sewers	No record of sewer flooding locally
Surface water	Natural Resources Wales surface water map shows extent

Sources from TAN15, Appendix 1E, Section 5

Figure 3 Distribution of surface water flood risk across the site



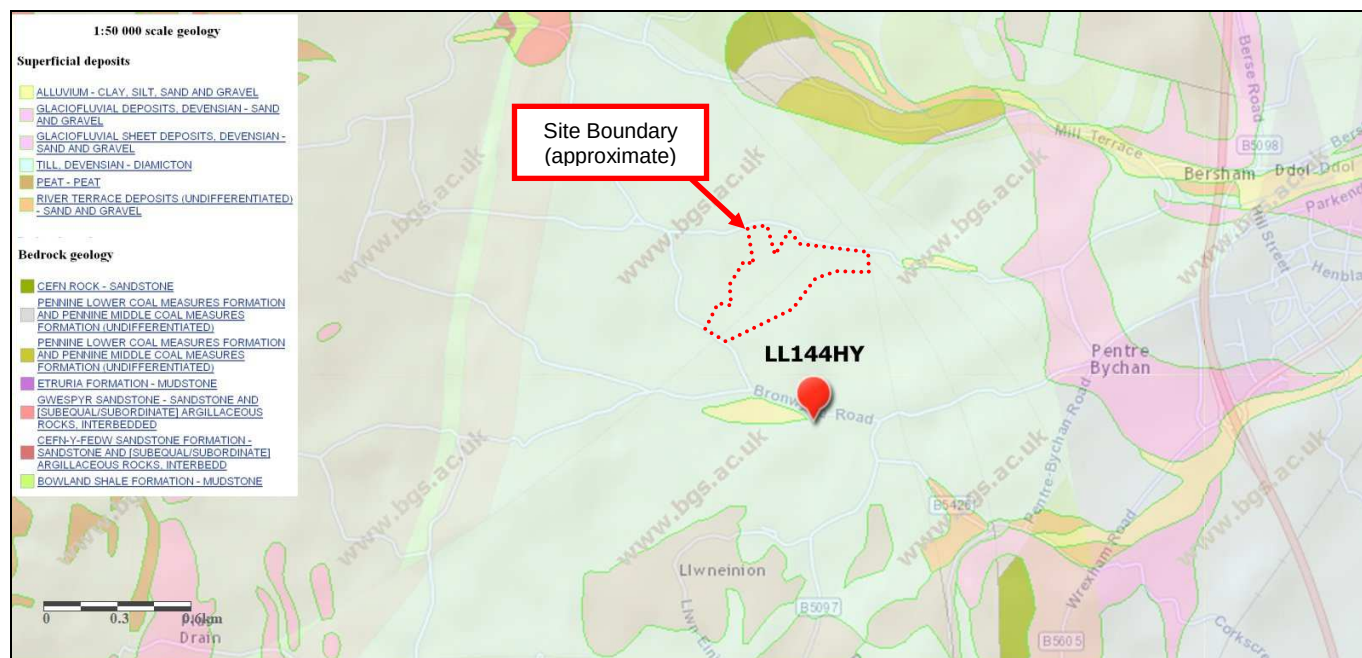
Source: <http://watermaps.environment-agency.gov.uk/wiyby/wiyby.aspx?lang=e&topic=ufmfs&layer=0&x=329308&y=348204&scale=10&location=LL14+4HY#x=329308&y=348204&scale=11>

2b. For each identified source, describe how flooding would occur, with reference to any historic records wherever these are available.

- An appraisal of each identified source, the mechanisms that could lead to a flood occurring and the pathways that flood water would take to, and across, the site.
- Inundation plans, and textual commentary, for historic flood events showing any information available on the mechanisms responsible for flooding, the depth to which the site was inundated, the velocity of the flood water, the routes taken by the flood water and the rate at which flooding occurred.

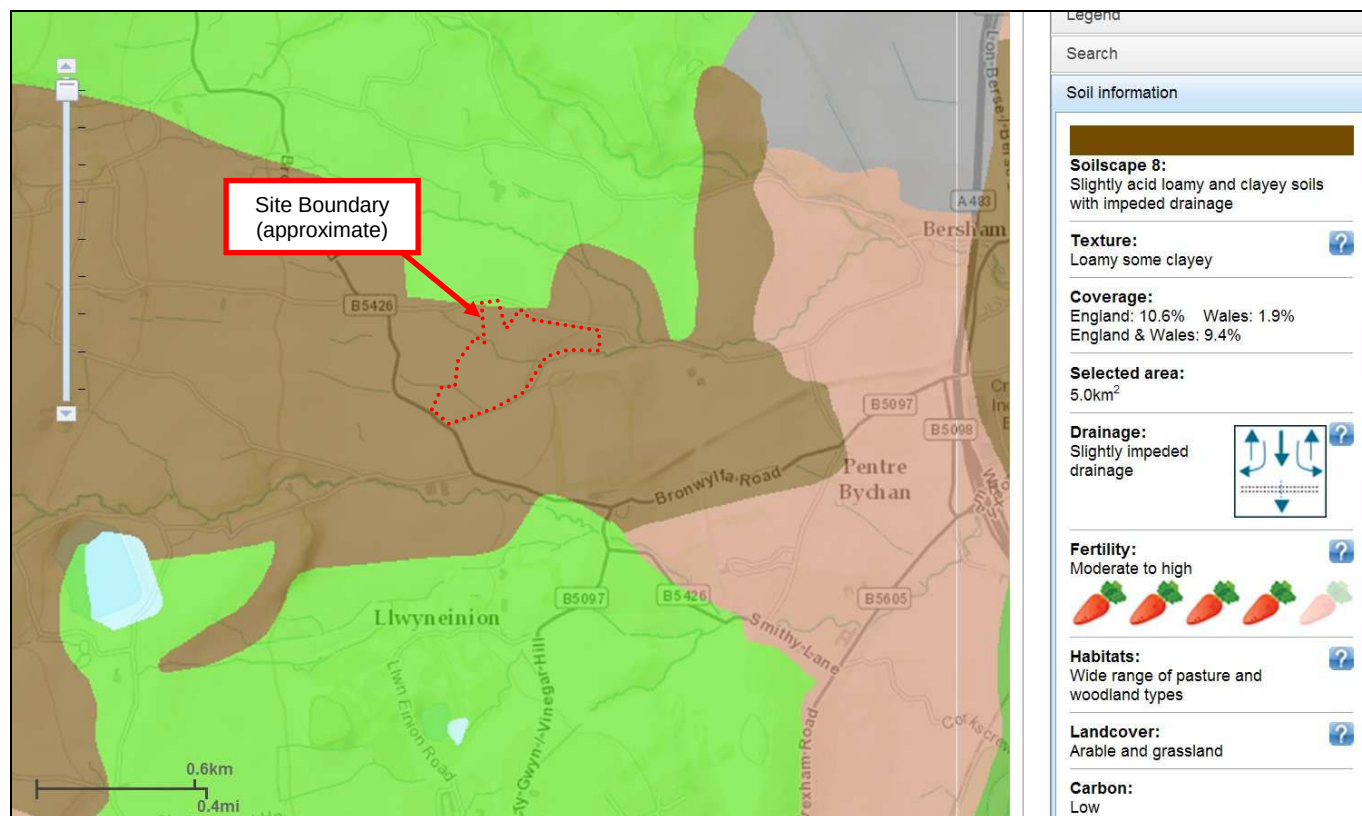
Surface water flooding is shown to run parallel with the streams in places, which follow relatively straight courses nearby (Figure 3). This may be a relic of drainage modification in the past. In order to better understand groundwater and surface water flooding at the site, the underlying geology is shown in Figure 4 and the soils in Figure 5.

Figure 4 Geology of the site and surrounding area



Source: <http://mapapps.bgs.ac.uk/geologyofbritain/home.html>

Figure 5 Soils of the site and surrounds



Source: <http://www.landis.org.uk/soilscapes/#>

The site and surrounds are underlain by superficial deposits, described in the key of Figure 4 as “Till, Devensian – Diamicton”. This refers to deposits of Pleistocene age and of glacial provenance, which are likely to be very poorly sorted and unconsolidated. The soils developed over the till in this area are described on the Cranfield website as “slightly acid loamy and clayey soils with impeded drainage” (Figure 5). The stream which forms the southern boundary of the site has been identified in FEH (Figure 6). The catchment characteristics were extracted but the only measure of interest is the percentage runoff (SPRHOST), which is listed as 43.73. This relatively high runoff is indicative of low catchment permeability.

This evidence suggests that the surface of the site has a low permeability, which may increase the risk of surface water flooding. For groundwater flooding to be a significant issue, there would need to be a means by which groundwater came to the surface, passing through the blanket of till and overlying soil. The Preliminary Flood Risk Assessment (PFRA) found no records of past groundwater flooding within the Wrexham County Borough Council area, as described in Section 3b. It is evident that surface water may be the only significant flood risk on site, concentrated along the flow paths identified in Figure 3.

Figure 6 Catchment of the stream forming the site's southern boundary



Source: FEH CD-ROM v3 (Centre for Ecology and Hydrology, 2009)

2c. What are the existing surface water drainage arrangements for the site?

- Details of any existing surface water management measures already in place, such as sewers and drains

The site is a series of fields (Figure 2) and drainage is provided by infiltration or runoff into the ditches which bound the fields.

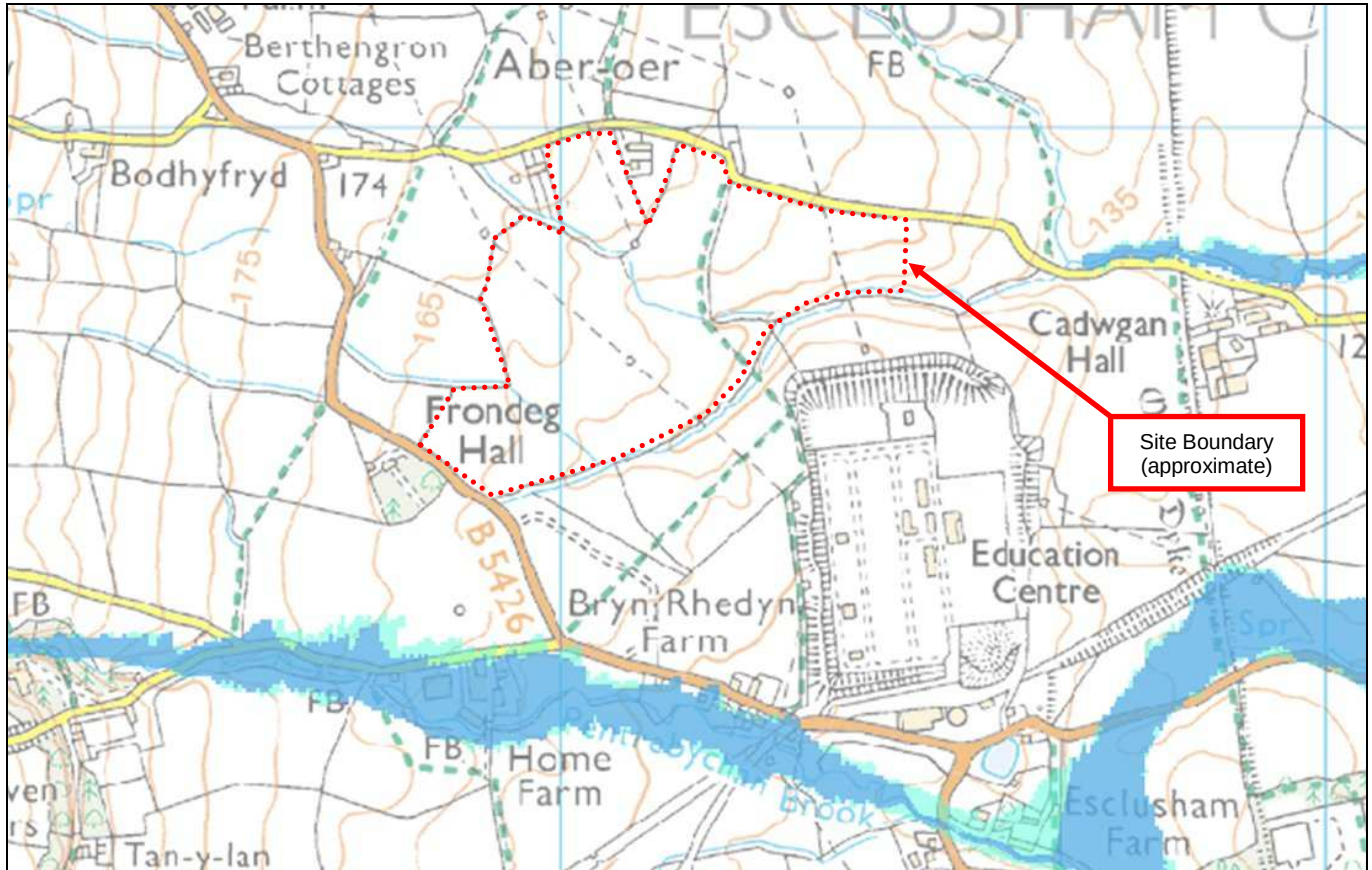
3. Probability

3a Which flood zone is the site within?

- The flood zones are defined in Figure 1 of TAN15.

This site is shown on Figure 7 to be entirely outside Flood Zone C, the extreme flood outline. It can be seen from Figure 4 that there are no significant alluvial deposits across the site, indicating that it lies within Fluvial Flood Zone A.

Figure 7 Fluvial Flood Zone Map



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3b If there is a Strategic Flood Risk Assessment covering this site, what does it show?

- The planning authority can advise on the existence and status of the SFRA.

The Lead Local Flood Authority (LLFA) of Wrexham County Borough Council has prepared a Preliminary Flood Risk Assessment (PFRA) available from the Environment Agency website¹. This states that "There were no records of past groundwater flooding within WCBC; this is due to the topography and geology of the area" (Wrexham County Borough Council, 2013, p.17). The PFRA also mapped sewer flooding, showing that there were no reports from the area of the site (PFRA, p.18). Based on flood risk from all sources and population criteria, the PFRA mapped Indicative Flood Risk Areas (IFRAs) across the borough (PFRA, p.25). The site was not included within an IFRA but this could be due to low population densities, rather than low flood risk.

3c What is the probability of the site flooding taking account of the contents of the SFRA and of any further site-specific assessment?

This may need to include

- a description of how any existing flood risk management measures affect the probability of a flood occurring at the site
- FRA Pro-forma

¹ <http://cdn.environment-agency.gov.uk/flho1111bvfm-e-e.pdf>

- supporting evidence and calculations for the derivation of flood levels for events with a range of annual probability
- inundation plans of, and cross sections through, the existing site showing flood extents and levels associated with events with a range of annual probability
- a plan and description of any structures which may influence the probability of a flood occurring at the site. This may include bridges, pipes/ducts crossing a watercourse, culverts, screens, embankments or walls, overgrown or collapsing channels and their likelihood to choke with debris.
- details of any modelling studies completed to define the existing degree of flood risk (Ref Chapter 3 of the PG)

Although there is a very low probability of fluvial flooding at this site, surface water flooding is shown in Figure 3 as having a low to moderate probability, along certain well defined flow paths. "Moderate", shown on Figure 3 using an intermediate blue colour, is defined by the Environment Agency surface water flood risk website as equivalent to an annual risk of between 1% and 3.3% AEP (ie. between 1:100 years and 1:30 years). It is clear from Figure 3 that a relatively small part of the site is expected to be affected, with the greater part of the site having a "very low" probability of surface water flooding, shown in white on Figure 3.

3d What are the existing rates and volumes of run-off generated by the site?

- This should generally be accompanied by calculations of run-off rates and volumes from the existing site for a range of annual probability events (see Section 8 of TAN15).

The soil map (Figure 5) shows that the site is underlain by "Slightly acid loamy and clayey soil with impeded drainage". Runoff estimation for small catchments based on the Marshall and Bayliss (1994) methodology uses five soil types, whose characteristics vary from permeable to impermeable, designated S1 to S5. For this analysis, the soil has been designated as S4, because of the impeded drainage. Since the Marshall and Bayliss method is only strictly valid on catchments of at least 0.5 km², that area has been used in the analysis to produce the results shown in Table 2.

Table 2 Estimate of greenfield and urban runoff from the site

Return period (years)	Runoff (l/s/ha)	
	rural	urban
QBAR	6.164	9.635
2	5.701	9.323
5	7.447	11.798
10	8.731	13.454
20	10.059	14.954
25	10.503	15.417
50	11.911	16.616
100	13.439	18.134
200	15.226	19.955
250	15.843	20.580
500	17.630	22.316
1000	19.665	24.310

Methodology based on Marshall D.C.W. & Bayliss A.C., 1994. Flood estimation for small catchments, IH Report No. 124, Institute of Hydrology, Wallingford and Hall, Hockin & Ellis

The "Rural" column represents an estimate of greenfield runoff, with the "Urban" column showing the effect of 31% of the site area being under impermeable surfaces (see Section 5).

4. Climate change

4a How is flood risk at the site likely to be affected by climate change?

- Sections 2.4 to 2.9 and Appendix 2 of TAN15 provide guidance on how to assess the impacts of climate change.

The general impacts of climate change on flood behaviour in England and Wales remain unclear. The FEH (Institute of Hydrology, 1999) describes a review of flood peak data to investigate possible trends. The analyses do not show that climate change has affected UK flood behaviour, but neither do they prove that it has not affected it. The NPPF requires a consideration of the impacts of climate change on the flood risk for any proposed development. The suggested mechanism for this is to allow for increases in peak flows of 20% to 2115 and peak rainfall of 30% over the same period.

The design life of this project is 25 years and over that period, relatively minor change is expected at the site. It is recommended that when sizing infiltration structures, the peak rainfall should be increased by 10%, as an allowance for climate change.

5. Detailed development proposals

5a Please provide details of the development layout, referring to the relevant drawings.

- Reference should be made to Figure 2 of TAN15.

The proposed site layout is shown in Figure 8, in which four areas have been selected from the greater site area. These are labelled Area A to Area D in Figure 8. The surface areas of solar panels proposed within each of the four parts of the site are shown in Table 3, set within a total fenced area of about 7.3 ha. The solar panels therefore cover some 31% of the fenced area.

Figure 8 Proposed layout of solar panels at the site

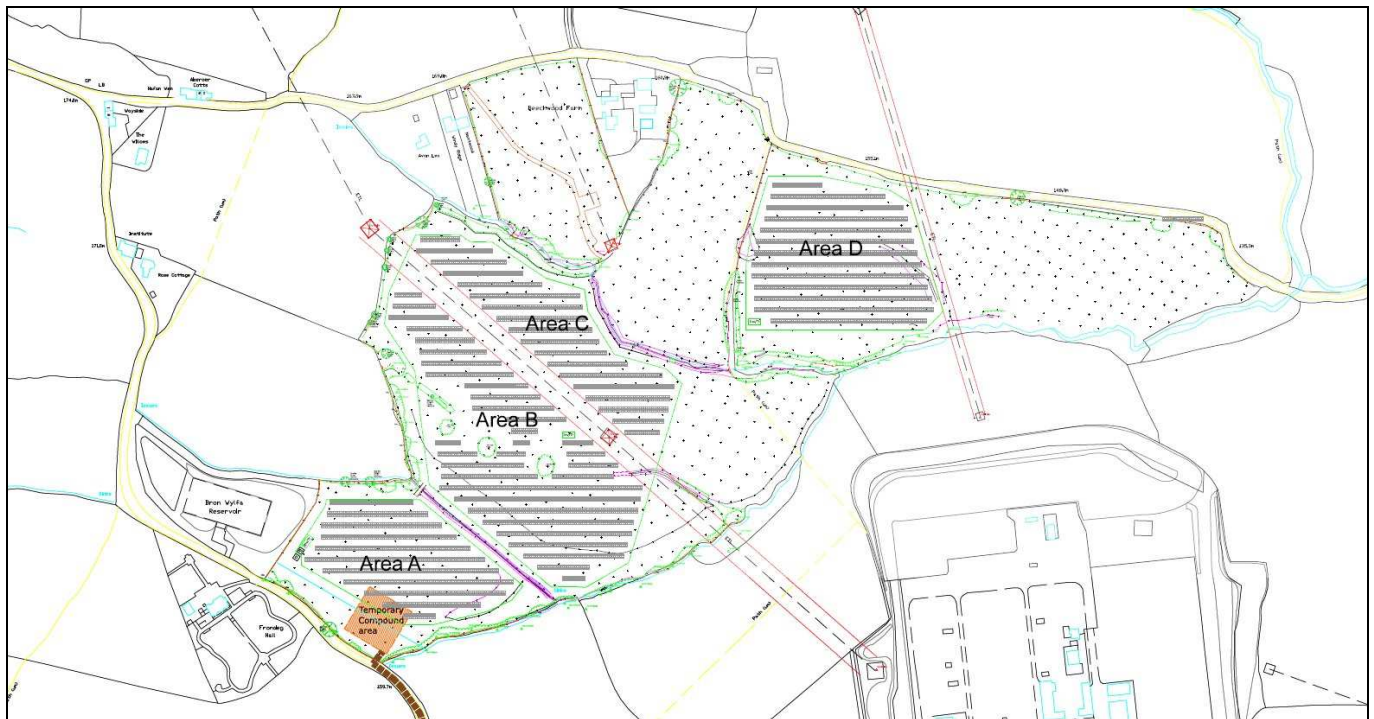


Table 3 Areas of solar panels (approximate)

	Area (m ²)
Area A	4,450
Area B	7,625
Area C	4,461
Area D	6,214
Total	22,750

5b Where appropriate, demonstrate how land-uses most sensitive to flood damage have been placed in areas within the site that are at least risk of flooding.

The site design includes a 7 m standoff from all the watercourses, as advised by Wrexham County Borough Council's Senior Flood Management Officer.

6. Flood risk management measures

6a. How will the site be protected from flooding, including the potential impacts of climate change, over the development's lifetime?

- This should include details of any proposed flood defences, access/egress arrangements, site drainage systems (including what consideration has been given to the use of SUDS) and how these will be accessed, inspected, operated and maintained over the lifetime of the development. This may need to include details of any modelling work undertaken in order to derive design flood levels for the development taking into account the presence of any new infrastructure proposed

As shown in Section 1b, power stations are considered by TAN15 as "Highly vulnerable development", presumably because of the potential consequences of a power outage during flooding. It was shown in Section 2 that fluvial flooding is very unlikely at the site and the only real flood risk is from surface water flooding, which is concentrated along flood flow paths which follow or run parallel with the streams, where they may represent the former routes of the stream channels (Figure 3).

The most severe risk of surface water flooding on the site is described as "moderate" in Figure 3, equivalent to an annual risk of between 1% and 3.3% AEP (Section 3c). The area expected to be affected is shown on Figure 3 to be relatively small and since these are stream lines or former stream lines with relatively small catchments, it is not expected that the flow will be very deep. The solar panels which have been proposed for the site would be raised above the surface by at least 0.7 m and even if flooding reached that depth, the equipment is able to resist periodic inundation, so should not suffer any long term effect through being flooded and those panels above flood waters would continue to supply power.

Even under the worst case scenario of a panel being taken out of commission, the rest of the grid would continue to operate normally. For these reasons, the operation of the solar farm would be only marginally affected or unaffected by flooding. Flood risk to people at the site would also be very small. People would not be required on site for power generation, only for maintenance and should that be required, it would be scheduled to avoid flooding. In summary, this land use is appropriate on sites such as this, even in parts of the site where there is a significant risk of surface water flooding.

7. Off site impacts

7a How will you ensure that your proposed development and the measures to protect your site from flooding will not increase flood risk elsewhere?

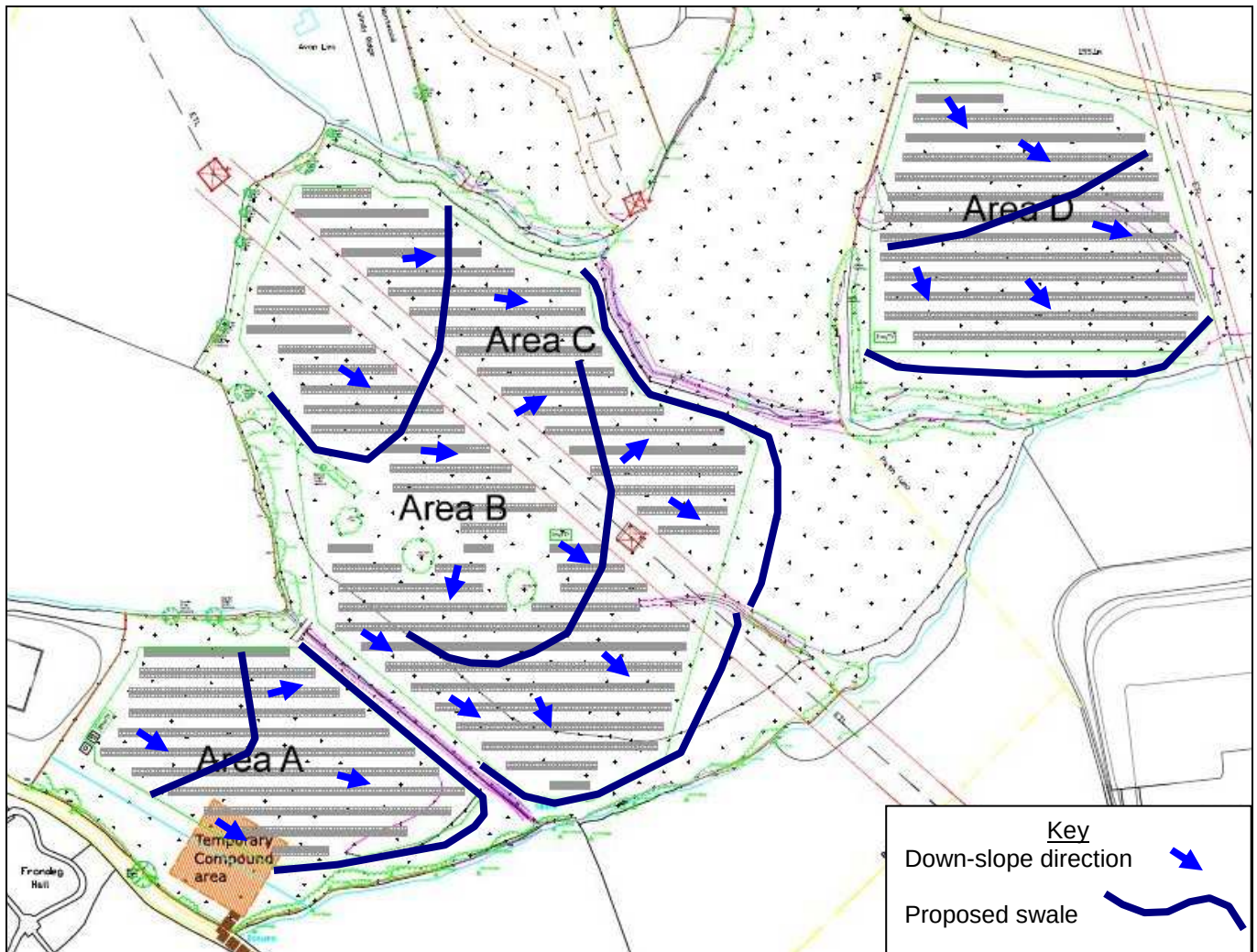
This should be over the lifetime of the development taking climate change into account. The assessment may need to include:

- Details of the design basis for any mitigation measures (for example trash screens, compensatory flood storage works and measures to improve flood conveyance).
- A description of how the design quality of these measures will be assured and of how the access, operation, inspection and maintenance issues will be managed over the lifetime of the development.
- Evidence that the mitigation measures will work, generally in the form of a hydrological and hydraulic modelling report.
- An assessment of the potential impact of the development on the river, estuary or sea environment and fluvial/coastal geomorphology. A description of how any impacts will be mitigated and of the likely
- longer-term sustainability of the proposals.

The proposed development would not significantly affect the existing flood flow paths. Even where a solar panel was positioned over a flood flow path, it would be supported on a structure with minimal material near ground level, so any flood flow would pass beneath it and would be virtually unaffected. It is proposed that the grass cover is retained beneath the solar panels and sheep would be kept within the field, to keep the grass cover short. Runoff from the surface of the field would therefore remain the same or similar to current rates.

The proposed development is not expected to lead to any increase in runoff, since the proposed layout provides ample opportunity for infiltration of runoff from the solar panels. However, It is recommended that mitigation is put in place at the site, to ensure that runoff from the solar panels does not increase flood risk downstream. It is recommended that broad swales are used to intercept any runoff across the surface of the fields. A possible arrangement is suggested in Figure 9. The precise location of the swales would depend on site issues and features of the development, so the arrangement suggested in Figure 9 should be regarded as indicative.

Figure 9 Proposed site layout



It is envisaged that these swales would form broad linear basins, circa 5 m wide. This width would promote infiltration across a broad wetted perimeter and ensure that the swales would not need to be very deep. As well as promoting infiltration more efficiently, broad shallow swales need not disrupt the arrangement of solar panels, which can be located over swales and bounding areas with equal ease.

The infiltration coefficient of the underlying soil is not known, so a conservative value has been selected. CIRIA (2007) give infiltration rates for loam in the range 0.1 m/hr to 0.001 m/hr and in order to be conservative, the slowest value has been used. Calculations of the depth of the swales were undertaken using the assumptions shown below, which could later be refined by infiltration testing on site.

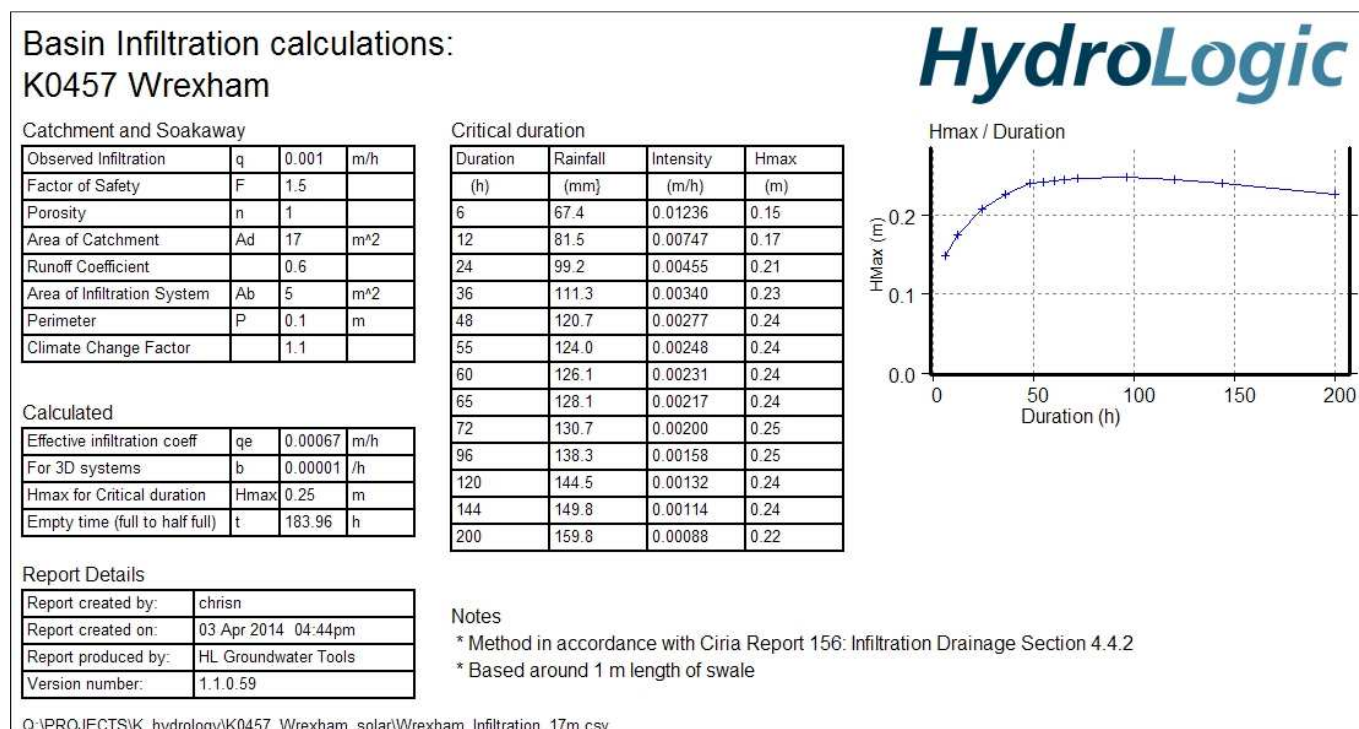
- 1) Where possible, swales to be laid parallel with the contours
- 2) Swales to be located above all watercourses, check weirs to be used to break the slope
- 3) All swales to have a 5 m width
- 4) Total swale length shown in Figure 9 is 1,350 m
- 5) With an impermeable area of 22,750 m² (Table 3), each metre of swale serves an average of 17 m² of impermeable catchment
- 6) Design rainfall totals derived from FEH (Centre for Ecology and Hydrology, 2009)
- 7) A runoff coefficient of 60% is assumed, a little over the SRPHOST of 44% (Section 2b)
- 8) Infiltration rate in the swales is taken as 0.001 m/hr
- 9) A factor of safety of 1.5 is used, as recommended by CIRIA (2007, p.4-31)
- 10) Peak rainfall at the site assumed to increase by 10%, due to climate change over the 15 year design life of the project.

It is recommended that the swales should be grassed over, forming a continuous grass cover with the rest of the area under solar panels. In this way if any one swale is overtopped, surface flow down slope would be intercepted by the swale below it. The lower most swale in Figure 9 is located close to the bounding stream and beyond the 7 m offset.

Where swales are routed across a change in slope, they should be broken by a "check weir", to ensure that they do not convey flow along their length. These check weirs can take the form of breaks in the feature, in which the ground is raised to retain the integrity of the higher swale. Runoff from higher land would not cross this break of raised ground but would be diverted into one swale or the other.

The calculation below is designed to dimension unit length (ie. one metre) of swale. The calculation is performed using Hydro-Logic Services' infiltration tool, based around the methodology recommended in CIRIA156. This tool assumes a rectangular cross-section, as may be found in soakaways. In practise, swales are more likely to have a curved base, typical of a basin, in which case they should be deepened to retain the volume and perimeter implied by Figure 10.

Figure 10 Calculated swale depth



The results (Figure 10) show that under the conservative assumptions listed above, the critical storm duration is between 72 hours and 96 hours, when swales would fill to a depth of 0.25 m. If the swales are constructed as basins, with curved upward-facing surfaces, this average depth implies that the maximum depth, between the deepest point and the outer lip should be in the order of 0.5 m. These dimensions are based on conservative assumptions and if conditions are found to be less severe than assumed, the system of swales shown in Figure 9 is likely to reduce runoff and so reduce flood risk downstream.

7b How will you prevent run-off from the completed development causing an impact elsewhere?

- Evidence should be provided that drainage of the site will not result in an increase in the peak rate or in the volumes of run-off generated by the site prior to the development proceeding.

See Section 7a.

8. Residual risks

8a What flood-related risks will remain after you have implemented the measures to protect the site from flooding?

- Designing for event exceedence on site drainage systems is covered in Chapter 4 of the Practice Guide. Guidance on other residual risks is provided in Chapter 6.

Residual risks include the possibility that heavy rainfall could cause individual swales to overtop and result in a breach of the outer lip. It is recommended therefore that the swales are inspected and maintained on a regular schedule, at least annually and after heavy rains.

8b How, and by whom, will these risks be managed over the lifetime of the development?

- Reference should be made to flood warning and evacuation procedures, where appropriate, and to likely above ground flow routes should sewers or other conveyance systems become blocked or overloaded. This may need to include a description of the potential economic, social and environmental consequences of a flood event occurring which exceeds the design standard of the flood risk management infrastructure proposed and of how the design has sought to minimize these – including an appraisal of health and safety issues.

Maintenance of the infiltration systems and associated infrastructure should be borne by the site owners.

REFERENCES

Author	Date	Title/Description
Centre for Ecology and Hydrology	2009	The Flood Estimation Handbook CD-ROM 3. Centre for Ecology & Hydrology, Wallingford, Oxon, UK.
CIRIA	2007	The SUDS Manual - CIRIA Report C697.
CIRIA	1996	Infiltration Drainage – Manual of good practice CIRIA Report C156.
Environment Agency		http://www.environment-agency.gov.uk/homeandleisure/floods/default.aspx (accessed 19 th Feb 2014)
Environment Agency	2010	Areas Susceptible to Groundwater Flooding (accessed 3 rd April 2014)
Institute of Hydrology	1999	Flood Estimation Handbook.
Kjeldsen, T.R.	2007	ReFH, The revitalised FRS/FEH rainfall-runoff method. FEH Supplementary Report No. 1.
Wallingford HydroSolutions Ltd.	2009	WINFAP-FEH 3.
Welsh Assembly Government	July 2004	Technical Advice Note 15: Development And Flood Risk
Wrexham County Borough Council	Adopted 2005	Unitary Development Plan (UDP) 1996-2011
Wrexham County Borough Council	undated	Preliminary Flood Risk Assessment (PFRA) Available from http://cdn.environment-agency.gov.uk/filho1111bvfm-e-e.pdf (Accessed 3 rd April 2014)