

**Ministry of Defence
(MoD), Metrix Ltd. And
Sodexo Ltd. /Welsh
Assembly
Government**

**Defence Technical
College and
Aerospace Business
Park - St Athan**

Flood Consequence Assessment

May 2009

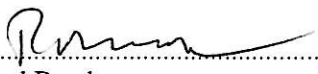
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Document Revisions

No.	Details	Date
1	RR146 - Draft FCA	26-02-2009
2	Revised to incorporate Metrix and WAG comments	01/04/2009
3	Draft to incorporate updated Surface water Drainage Strategy	22-04-2009
4	Inclusion of final comments and revised Boverton Brook hydrology. Issued as C185.	08-05-2009

Executive Summary

This report presents the findings of a Flood Consequence Assessment (FCA) undertaken by Entec UK Ltd (Entec) for Metrix. The report is in support of outline planning applications for the redevelopment of the St Athan MOD site, plus support for a detailed planning application for the developments highway accesses.

The St Athan development site is located in south-east Wales, within the administrative district of the Vale of Glamorgan approximately 8 miles west of Barry and 12 miles north-west of Bridgend. The site benefits from good transport links being situated approximately 4 miles west of Cardiff Airport and approximately 14 miles south of Junction 33 of the M4. The administrative centre for the Vale of Glamorgan is Barry, with other medium sized settlements including the towns of Llantwit Major, Penarth and Cowbridge situated within the administrative boundary. Smaller villages are located in the immediate area surrounding the site including the villages of Llanmaes, Flemingston, Gileston and the hamlet of Picketston.

The land surrounding the site comprises mainly open countryside which is in agricultural use. There are a number of farms located in the immediate area including Great House Farm to the north, Boverton Mill Farm to the south and Pant Yr Awel Farm, Rock Farm and Church Farm to the east.

The main site covers an area of 293ha, with an adjacent 160ha included in the proposals.

This FCA has been prepared following consultation with the Environment Agency Wales and conforms to the requirements of *Technical Advice Note 15 (TAN15): Development and Flood Risk*. The Welsh Assembly Government's (WAG) accompanying TAN15 development advice maps, alongside the Environment Agency flood maps and more detailed flood mapping prepared for this FCA have been used to inform the assessment of flood risk.

The site at present consists of several different components. Broadly these are the West Camp, (Home to Special Forces Support Group) and East Camp (predominantly the maintenance & repair of aircraft (aerospace business), Service Families Accommodation, military defence training, logistics and storage), a main runway plus secondary runway and land at Picketston (storage facilities).

Ultimately, the redeveloped site will again consist of several different components: Service Families Accommodation (SFA) will be at four separate locations close to the site (Tremains Farm, Picketston South West, North of West Camp and Castleton). The Aerospace Business Park will be further developed, split between two areas north and south of the main runway. East camp will be dedicated to military residential training and the Defence Technical College (DTC), whilst Picketston will be developed as a 'sports, recreation and training area'. At Castleton to the east of St Athan a Field Training Area will be created.

In support of these developments, access improvements are to be made to the B4265 and in particular a new Northern Access corridor, linking the north of the St Athan site with the B4265 is to be constructed to serve the DTC and ABP. As the new Northern Access Road (NAR) passes adjacent to areas of Flood Zone C2 and crosses the Boverton and Llanmaes Brooks flood modelling has been included undertaken. This has been used to inform the design of the Llanmaes Brook crossing.

A new sewage pumping station will be constructed on site, with a rising main taking sewage from the development to the Llantwit Major WwTW 4.5 km to the north-west.

Adjacent to the main sites flat plateau location are three watercourses: the Boverton Brook to the west, the Nant y Stepsau to the northeast, and the Rhyl stream to the southeast. In terms of flood risk, in Boverton downstream of the St Athan site along the Boverton Brook there are approximately 6 properties at risk of flooding (as defined by TAN15 Flood Zone C, with a probability of flooding greater than 0.1% in a given year). Flood risk along the Nant y Stepsau is limited to the adjacent grazing land and minor local roads. Along the Rhyl Stream several properties in St Athan are understood to be at risk of flooding.

The majority of the main site is located in TAN15 Flood Zone A: i.e. within an area with a less than 0.1% probability of flooding from fluvial or tidal sources in a given year. Therefore, in terms of flood risk the major issue at St Athan will be ensuring that surface water is appropriately managed so as not to increase flood risk to people and property on-site and downstream of the site. However, there are areas of Flood Zone C within the development areas, principally parts of the Tremains Farm and North of West Camp SFA areas. The parts of these sites located in Flood Zone C will be used as open space, with built development directed to areas in Flood Zone A. The modelled flood outlines have also been used to ensure the route of the new NAR is placed in Flood Zone A.

With regards to the Picketston DTC and Picketston South West SFA areas, there is a small residual flood risk associated with the small ditch-courses passing through these areas. The Picketston DTC's southern boundary follows the upper ditch-course of the Nant y Stepsau. However, given the small catchment here (less than 1.5km²) flood risk would be limited to a thin strip along the ditch. Proposals have been developed to improve this watercourse as part of the SWDS for the redevelopment of the Picketston area for the DTC. The upper ditch-course of the Boverton Brook is to be diverted as part of the development in this area.

Detailed schemes for the proposed diversion of the upper Boverton Brook and for improvements to the Nant y Stepsau ditch-course (see 'DTC Proposed Drainage Strategy' figure in **Appendix C**) as part of the DTC Picketston drainage will be further developed at detailed design stage and submitted to the Environment Agency Wales for agreement. This will ensure that the diversion scheme does not cause an increase to flood risk downstream. The diversion of part of the upper Boverton Brook ditches, improvements to the Nant y Stepsau corridor as part of the DTC Picketston redevelopment and the proposed SuDS drainage improvements in general will upon redevelopment ensure that the existing localised surface water flooding along the Boverton to Eglwys Brewis road is improved. In addition, the net transfer of part of the Boverton Brook catchment to the Nant y Stepsau will provide a small but important contribution to reducing flood risk in the Boverton Brook catchment. The reduction in catchment area (net transfer 34.5ha) will provide a small reduction to flood flows.

The ABP (north and south), the SAR, RDH, DTC East Camp, ETA, FTA and the Castleton SFA sites are all located solely in Flood Zone A, at minimal risk of flooding.

In all cases, surface water management by SuDS has been identified to maintain runoff at the greenfield rates provided by the Environment Agency (7.4 l/s/ha for the Nant y Stepsau and Rhyl Stream, and 3.9 l/s/ha for the Boverton Brook). A 20% (30% for SFA areas) allowance for increased rainfall intensity due to climate change has been incorporated into the design of the surface water drainage system. The differences being due to the differing design lives (100 years for residential, 50 years for other aspects of the development). The proposed SuDS consist of predominantly dry features such as swales and over-wide ditches, or infiltration based

SuDS such as source control (permeable paving) and infiltration trenches/blankets and soakaways (permanently wet features are to be avoided due to the risk of bird-strike incidents associated with air craft). Adjacent to the runway and the ABP, underground storage is proposed. Management and maintenance arrangements will be put into place for each set of SuDS, via designated responsible organisations.

Discharge to the Boverton Brook and Nant y Stepsau will be managed to greenfield rates alongside localised improvements to the upper ditch-course and culverts where appropriate. The overall site discharge rate to the Rhyl Stream will not be increased by the redevelopment.

This FCA presents a summary of the drainage proposals for the redevelopment. More detail on the proposals is contained within the DTC St Athan - Surface Water Drainage Strategy (**Appendix C**). Calculations and designs for the proposed Sustainable Drainage System (SuDS) have been based on the surface water management design parameters agreed with the Environment Agency Wales during the preparation of this FCA.

In this FCA, **Section 2** sets out the redevelopment proposals in more detail, **Section 3** details the assessment of flood risk, **Section 4** details surface water management proposals, **Section 5** provides details of the recommended mitigations and **Section 6** details the FCA's conclusions.

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1. Introduction

1.1 Brief

This report presents the findings of a Flood Consequence Assessment (FCA) undertaken by Entec UK Ltd (Entec) for Metrix. The report is in support of outline planning application for the redevelopment of the St Athan MOD site, located 20 km west-south-west of Cardiff. The main site covers an area of 293ha, with an adjacent 160ha included in the proposals.

This FCA has been prepared following consultation with the Environment Agency Wales and conforms to the requirements of *Technical Advice Note 15 (TAN15): Development and Flood Risk*. The Welsh Assembly Government's (WAG) accompanying TAN15 development advice maps have been used to inform the assessment.

The site is currently an operational military facility, and this FCA is intended to support the outline plans developed for the reconfiguration and future redevelopment of the site. A number of consultants and agencies are working on various elements of the St Athan proposals. Entec has been commissioned to carry out an Environmental Impact Assessment (EIA) and to produce an Environmental Statement (ES) in support of both outline planning applications. This FCA is in support of the ES, and draws on the individual studies carried out by others for their elements of the development.

In this FCA flood risk from all potential sources has been investigated, and supplemented with hydraulic modelling of the Boverton and Llanmaes Brooks along the route of the proposed Northern Access Road (NAR) and adjacent to the Tremains Farm and North of West Camp Service Families Accommodation (SFA) sites. Calculations and designs for the proposed Sustainable Drainage System (SuDS) produced by the various consultants working on elements of the project have been developed into a Surface water Drainage Strategy (SWDS), this has been developed based on the Environment Agency's requirements for surface water management. The Environment Agency has been consulted on surface water management, and their requirements were defined in the minutes of a meeting held on the 23/07/08. At this meeting, for existing development, a key requirement that runoff rates should not be increased above existing rates was stated, and ideally runoff rates should be reduced by 20% below existing rates, in order to contribute to reducing flood risk elsewhere in the catchment. Runoff from redeveloped areas of the site will be attenuated to greenfield runoff rates. Further details are given in **Section 4** and **Appendix C**.

1.2 Scope

This report covers the following aspects:

- A description of the site and the proposed developments (**Section 2**);
- Flood Consequence Assessment (FCA) (**Section 3**);
- Surface Water Management (**Section 4**); and
- Proposed Mitigations (**Section 5**); and

-
- Recommendations and Conclusions (**Section 6**);

1.3 Consultations and Site Visit

Consultations have been undertaken with:

- Environment Agency Wales – Jackie Walters – Surface Water Management meeting minutes (meeting held 23/07/08), guidance on the FCA scope and the requirements for surface water management and SuDS (letter received 15/08/08 – confirmation of meeting minutes and supply of Greenfield runoff rates);
- Vale of Glamorgan Council – availability of a SFCA. Enquiries were made to establish if an SFCA had been prepared for the Vale of Glamorgan region. Understood that no study is currently available. Meeting held on the 27th March 2009 with Allan Bosley to discuss any flood risk information held by the Vale of Glamorgan. Limited information is held, relating to localised surface water runoff in adjacent villages;
- Environment Agency – Christian Servini - hydrological data (letter/data received 12/09/08). Data included flow records for Gigman Bridge (River Thaw, of which the Rhyl Stream and Nant y Stepsau are tributaries) and two gauging stations in Llantwit Major on the Boverton Brook;
- Consultant Meeting 23rd January 2009 – meeting to discuss Boverton Flood Extents and SFA and NAR layouts;
- Public consultation – Environmental Interest Group – February 24th. Discussion with members of the public on their concerns with regards to the development.
- Environment Agency 26th February 2009 – meeting to discuss Boverton Brook modelling and development adjacent to the Nant y Stepsau. Unadjusted FEH catchment descriptors give a poor representation of the catchments response to rainfall. Subsequent discussions with regards to previous Environment Agency Wales investigations of the Boverton Brook’s hydrology and the need for further analysis using historic data and the WinFAP FEH v2 catchment pooling approach.

Site visits:

- A site walkover was undertaken on the 13th October 2008; and
- Boverton Brook hydraulic model ground truthing – 11th February 2009

Data supplied:

- Various OS mapping tiles;
- A digital elevation model of St Athan has been prepared by Scott Brownrigg, with additional area-specific topographic surveys commissioned as required for each element of the scheme;
- A topographic survey of hydraulic structures and channel cross-sections was completed by Azimuth Surveys Ltd in November/December 2008; and

- LIDAR data has been purchased from the Environment Agency Geomatics Group (December 2008) for the Boverton Brook and Nant y Stepsau corridors.

2. Site Description

2.1 Existing Site

Figure 2.1 shows the location of the planning application area adjacent to the village of St Athan. **Figure 2.2** shows the individual redevelopment locations. **Appendix A** shows the proposed redevelopment. Photographs of the site are included in **Appendix B**.

The St Athan development site is located in south-east Wales, within the administrative district of the Vale of Glamorgan approximately 8 miles west of Barry and 12 miles north-west of Bridgend. The site benefits from good transport links being situated approximately 4 miles west of Cardiff Airport and approximately 14 miles south of Junction 33 of the M4. The administrative centre for the Vale of Glamorgan is Barry, with other medium sized settlements including the towns of Llantwit Major, Penarth and Cowbridge situated within the administrative boundary. Smaller villages are located in the immediate area surrounding the site including the villages of Llanmaes, Flemingston, Gileston and the hamlet of Picketston.

The land surrounding the site comprises mainly open countryside which is in agricultural use. There are a number of farms located in the immediate area including Great House Farm to the north, Boverton Mill Farm to the south and Pant Yr Awel Farm, Rock Farm and Church Farm to the east.

The main site is centred on grid reference ST 004 686 and is located to the north of the B4265, with multiple access points from this road and the surrounding perimeter roads (see **Figure 2.1**). The main site's existing access is from the existing B4265. Access roads to and from the site are generally located in Flood Zone A (**Figure 3.2**), although the B4265 passes through areas of Flood Zone B and C2 associated with the Afon Thaw to the east and the Boverton Brook immediately to the west of the site. Currently the perimeter road between the main site and the Picketston site experiences periods of localised standing water at times of heavy rainfall. **Appendix B** contains photographs of the watercourses adjacent to the site.

The present site (**Figure 2.1**) consists of:

- Red Dragon Hangar (predominantly the maintenance & repair of aircraft (aerospace business));
- East Camp (predominantly the maintenance & repair of aircraft (aerospace business), service families accommodation, military defence training, logistics and storage);
- West Camp (service family accommodation, logistics and storage);
- Picketston (storage facilities and engineering);
- Airfield - runways and taxiways;
- Farmland.

The majority of sewerage from the existing site is routed to the Llantwit Major WwTW, located 4.5 km west of the site. Sewerage from the south-eastern area of the site is though routed to the Aberthaw WwTW, located 2 km southeast of the site.

2.2 Proposed Development

Metrix, the Ministry of Defence (MoD) and the Welsh Assembly Government are submitting planning technical applications to support the major redevelopment of MoD St Athan in South Wales as a military training facility, and a major aerospace centre of excellence. This facility will be known as “*Defence Technical College and Aerospace Business Park - St Athan*” (hereafter referred to as St Athan). The proposed development will occur over an area of approximately 293 hectares at the base itself, plus approximately a further 160 hectares adjacent to the site, although it will also include associated infrastructure to support the new development, such as additional accommodation and leisure facilities for service personnel and families, training facilities, the diversion of an existing road, new drainage infrastructure and off site improvements to a local sewage treatment works. The key components to the redeveloped site will be:

- Defence Technical College;
- Aerospace Business Park;
- Service Families Accommodation, including works to St Athan Golf Course;
- Field Training Area;
- Northern Access Road (NAR);
- Associated road improvements (Eglwys Brewis road corridor, southern access road and various improvements to the B4265);
- New rising foul main to Llantwit Major WwTW.

This Flood Consequence Assessment (FCA) considers the cumulative potential impacts of the individual elements of the redevelopment on surface water runoff and flood risk.

As the current site comprises a wide range of functions, parts of the current site fall into the highly vulnerable and less vulnerable development categories of the TAN15 vulnerability classification, detailed in **Table 2.1**. Upon the redevelopment of St Athan there will be no change in this range of vulnerability classifications, although the proportions of buildings in each category will change. For the majority of the St Athan site, where development is proposed is located in TAN15 Flood Zone A (less than 0.1% probability of flooding in a given year, and no geological indicators of flooding), the present and future uses are entirely appropriate. However, associated parts of the development are located in Flood Zones B and C, and will require further investigation. These areas include the NAR, and parts of the SFA sites (Tremains Farm, North of West Camp and Picketston South West).

Table 2.1 TAN15 Flood Vulnerability Classification

Development Category	Types
Emergency Services	Hospitals, ambulance stations, fire stations, police stations, coastguard stations, command centres, emergency depots and buildings used to provide emergency shelter in times of flood.
Highly Vulnerable Development	All residential premises (including hotels and caravan parks), public buildings (e.g. schools, libraries, leisure centres), especially vulnerable industrial development (e.g. power stations, chemical plants, incinerators), and waste disposal sites.
Less Vulnerable Development	General industrial, employment, commercial and retail development, transport and utilities infrastructure, car parks, mineral extraction sites and associated processing facilities, excluding waste disposal sites.

The proposals for the St Athan site are shown in **Appendix A**. Details of the individual proposals are provided below.

2.2.1 Defence Technical College (predominantly located on the present East Camp and Picketston areas);

East Camp – Figure 2.2 and Table 2.2

Programmed redevelopment of the existing East Camp area as a new Defence Technical College (specific facilities include: Learning Resource Centre classrooms, headquarters building, sports centre, messes, SLA, museum, medical and dental centre, military house offices, sports facilities) see ‘DTC proposed drainage strategy’ figure in **Appendix C**. This entire site is located within Flood Zone A (less than 0.1% probability of flooding in a given year from fluvial sources); a Surface Water Drainage Strategy (SWDS) has been produced to ensure that surface water is appropriately managed. At present the entire site is drained to the Rhyl Stream, which is located 0.3km south of the East Camp’s southern boundary. Upon redevelopment this discharge point will be shared with the ABP South. It is proposed that the redeveloped areas discharge rate will not exceed the existing discharge rate. The new drainage will utilise elements of the existing site drainage, supported where appropriate by new pipework. Due to the topography of the area, which slopes to the south, SuDS attenuation features will be located along the southern boundary of the site, north of the main runway. It is proposed that these features will be underground storage tanks, since the location adjacent to the runway precludes the use of open features which may attract birds and other animals to the runway area. The SuDS will attenuate flows to greenfield rates and ensure that the discharge to the Rhyl Stream (in combination with the discharge from the ABP South area) which also joins the Rhyl Stream at this existing discharge point does not exceed the existing un-attenuated discharge. Further details of the drainage proposals for this component can be found in **Section 4** and the DTC St Athan - Surface Water Management Strategy (**Appendix C**).

Adjacent to Red Dragon Hangar – Figure 2.2 and Table 2.2

Proposals include several additional buildings here – i.e. training centre extension, Flight Line, RID and FM stores and the Energy centre, see ‘DTC proposed drainage strategy’ figure in **Appendix C**. This area is Flood Zone A (less than 0.1% probability of flooding in a given year from fluvial sources) a SWDS has been produced to ensure that surface water is appropriately managed. At present this area drains north to the Nant y Stepsau, an arrangement which will

not be altered by the proposals. In terms of SuDS the buildings in this area will utilise the existing drainage basins constructed in support of the Red Dragon Hangar. The two attenuation basins here were designed for a larger impermeable area than exists at present, or is proposed. Adjustments to the basin capacity and discharge rate will be required as these were designed to the 1 in 30 year standard, rather than the 1 in 100 year plus climate change. The ditch-course that forms the upper Nant y Stepsau runs parallel to, but 10 to 20m north of the northern boundary of this area, the watercourse does not pose a flood risk to this area as it has a limited catchment area (1 km²) and is set within a shallow linear depression alongside the Boverton – Eglwys Brewis road. Further details of the drainage proposals for this component can be found in **Section 4** and the DTC St Athan - Surface Water Management Strategy (**Appendix C**).

Picketston – Figure 2.2 and Table 2.2

This area will be developed as an External Training Area (ETA), with sports facilities including pitches, a swimming pool sports hall and a running track, crèche, community centre workshops; a 150 bed hotel are also included in these proposals. Elements of the existing storage buildings/facilities will remain, see ‘DTC proposed drainage strategy’ figure in **Appendix C**. Ditches forming the upper Boverton Brook (catchment area less than 1.5km²) run through the area at present, with areas of the southern fringe being located within Flood Zone C2 associated with main channel of the Boverton Brook. Immediately east of the Boverton Brook the Nant y Stepsau runs along the sites southern boundary. The ditch-course that forms the upper Nant y Stepsau runs parallel to, and just within the southern boundary of this area, the watercourse does though pose a limited flood risk to this area as it has a limited catchment area (effectively between 0.0 and 1.5km²) and is set within a shallow linear depression alongside the Boverton – Eglwys Brewis road. Otherwise the majority of the site is in Flood Zone A (less than 0.1% probability of flooding in a given year from fluvial sources). A SWDS has been produced to ensure that surface water is appropriately managed. The hydraulic modelling of this watercourse is discussed in **Section 3** of this report. As part of the redevelopment it is proposed to divert the upper reaches of the Boverton Brook. This diversion will consist of the very upper ditch/watercourse, which is categorised as Ordinary Watercourse and is upstream of the Environment Agency Wales Main River stretch. It is proposed to replace the existing watercourse corridor with like for like plus (minor) betterments for habitat/flood risk to ensure the modification does not result in any detriment on these accounts. Surface water from this site passes to both the Boverton Brook and Nant y Stepsau catchments. Comparing existing runoff routes and contributing areas, with the proposed drainage layout indicates that the redevelopment will result in a net diversion of 34.5ha from the Boverton Brook catchment to the Nant y Stepsau. This is discussed further in **Section 4.1.4**. Proposed SUDS include three open attenuation basins, a storage tank, and the use of the some sports pitches for shallow storage (0.1m depth) of extreme rainfall events. Details of the drainage proposals for this component can be found in **Section 4** and the DTC St Athan - Surface Water Management Strategy (**Appendix C**).

Table 2.2 Defence Technical College – TAN15 summary

Development	TAN15 Flood Zone	TAN15 Justification Test Met?	Further Investigation
DTC – East Camp	Flood Zone A	Yes – located within the lowest risk TAN15 flood zone.	SWDS required. See Appendix C .

Development	TAN15 Flood Zone	TAN15 Justification Test Met?	Further Investigation
DTC – Adjacent to RDH building	Flood Zone A	Yes – located within the lowest risk TAN15 flood zone.	SWDS required. See Appendix C .
DTC – Picketston	Flood Zone A and C2	Majority of site appears to be located within the lowest risk TAN15 flood zone. Potentially a strip of land at risk of flooding (Flood Zone C2) along the existing Nant y Stepsau ditch. Test met if all development located in Flood Zone A.	SWDS required. See Appendix C . Improvements to be made to the upper Nant y Stepsau, see section 2.2.5 of this report.
ETA	Flood Zone A	Yes – located within the lowest risk TAN15 flood zone. Located in the northern portion of the Picketston site. Adjacent to some field drains, but no significant watercourses.	SWDS proposals included with the DTC Picketston proposals.

The TAN15 flood map (**Figure 3.2**) only indicates limited areas of Flood Zone B (geological indicators of flooding), located outside of these development areas.

2.2.2 Aerospace Business Park; (split between ABP north and ABP south);

Aerospace Business Park – North – Figure 2.2 and Table 2.3

Programmed redevelopment of the eastern portion of West Camp as the northern component of the ABP. Access to this area of the ABP will be from the new NAR. The initial redevelopment will comprise the installation of the main infrastructure and development of some ABP buildings, with additional development of buildings occurring in future on a market led basis, see the ‘Overall WAG Drainage Strategy’ figure in **Appendix C**. This entire site is located within Flood Zone A (less than 0.1% probability of flooding in a given year from fluvial sources). The very upper stretch of the Nant y Stepsau runs parallel to but 10 to 20m north of the northern edge of the site in a shallow linear depression alongside the existing Boverton to Eglwys Brewis road. At this point the ditch-course is a poorly defined, with a catchment area of less than 0.2km². Flood risk from this ditch-course is very limited and does not extend into the area of the ABP north.

At present site drainage is split between the Boverton Brook and Nant y Stepsau catchments. Whilst the natural slope of the land is towards the upper Nant y Stepsau ditch-course, the existing artificial drainage system collects surface water and routes it to the Boverton Brook catchment. The redevelopment will result in the surface water again being discharged to the topographical catchment (i.e. Nant y Stepsau), which would have been the situation before the original development of the site. This is discussed further in **Section 4.1.4**.

A SWDS has been produced to demonstrate how surface water will be managed by the development in order to prevent an increase in downstream flood risk. The proposals for the site mean that in order to keep the replacement drainage system for the ABP north separate from the MOD’s drainage system under the rest of West Camp, flows from the area redeveloped as the ABP north will be routed entirely to the Nant y Stepsau. The new drainage will utilise elements of the existing site drainage, supported where appropriate by new pipework. SuDS attenuation features will be located throughout the site, with some further attenuation provided before discharge to the Nant y Stepsau. Due to the location adjacent to the secondary runway it

is proposed that these features will be underground infiltration and storage tanks, since the location adjacent to the runway precludes the use of open features which may attract birds and other animals to the runway area. It is proposed to recycle some of the water stored for use within the ABP north buildings. Details of the drainage proposals for this component can be found in **Section 4** and the DTC St Athan - Surface Water Management Strategy (**Appendix C**).

Aerospace Business Park – South – Figure 2.2 and Table 2.3

Programmed development of the area of south of the main runway as the southern component of the ABP. Initially access to this area of the ABP will continue to be across the main runway from the northern component of the ABP, but as redevelopment progresses a new access road direct to the B4265 will be created. The initial development will comprise the installation of the main infrastructure and development of some ABP buildings, with additional development of buildings occurring in future on a market led basis, see the ‘Overall WAG Drainage Strategy’ figure in **Appendix C**. This entire area where development is proposed is located within Flood Zone A (less than 0.1% probability of flooding in a given year from fluvial sources). The upper stretch of the Rhyl Stream runs through a steep-sided valley to the southeast of the ABP south, any areas of fluvial flood risk are therefore restricted to the valley bottom 5 to 10m below the areas where ABP development will occur.

A SWDS has been produced to demonstrate how surface water will be managed by the development in order to prevent an increase in downstream flood risk. At present drainage from this area follows the local topography towards the Rhyl Stream. The development will not change this routing of runoff, and flows will continue to be routed to the Rhyl Stream. However, flows will be managed by an artificial drainage system (SuDS) with attenuation features to attenuate flows entering the Rhyl Stream. Due to the location adjacent to the main runway it is proposed that these features will be underground infiltration and storage tanks, since the location adjacent to the runway precludes the use of open features which may attract birds and other animals to the runway area. It is proposed to recycle some of the water stored for use within the ABP south buildings. The SuDS will attenuate flows to greenfield rates and ensure that the discharge to the Rhyl Stream (in combination with the discharge from the DTC area at East Camp) which also joins the Rhyl Stream at this existing discharge point does not exceed the existing un-attenuated discharge. Details of the drainage proposals for this component can be found in **Section 4** and the DTC St Athan - Surface Water Management Strategy (**Appendix C**).

Table 2.3 Aerospace Business Park – TAN15 summary

Development	TAN15 Flood Zone	TAN15 Justification Test Met?	Further Investigation
ABP North	Flood Zone A	Yes – located within the lowest risk TAN15 flood zone.	SWDS required. See Appendix C .
ABP South	Flood Zone A	Yes – located within the lowest risk TAN15 flood zone.	SWDS required. See Appendix C .

The TAN15 flood map (**Figure 3.2**) only indicates limited areas of Flood Zone B (geological indicators of flooding), located outside of these development areas.

2.2.3 Service Families Accommodation;

Tremains Farm – Figure 2.2 and Table 2.4

It is planned to place 153 housing units on the Tremains Farm site, which is adjacent to the Boverton and Llanmaes Brooks. These watercourses have been modelled in HEC-RAS (see **Section 3**) and the model outputs used to inform site layout. Consequently, housing units will be located at elevations above the 0.1% AEP flood event + blockage flood levels along the Boverton Brook / Llanmaes Brook – i.e. entirely in Flood Zone A. Total area of 6.5 ha (all greenfield at present), see St Athan drainage masterplan in **Appendix C**. Therefore the only further flood risk requirement for this site will be a SWDS, required in order to demonstrate how surface water will be managed by the development in order to prevent an increase in downstream flood risk. It is proposed to use a combination of SuDS, comprising source control (underground storage and infiltration) and site control (attenuation basins). Details of the drainage proposals for this component can be found in **Section 4** and the DTC St Athan - Surface Water Management Strategy (**Appendix C**).

Picketston South West – Figure 2.2 and Table 2.4

It is planned to place 109 housing units on the two areas that comprise the Picketston South West site. The south-eastern corner of eastern portion is adjacent to the upper Boverton Brook. This watercourse has been modelled in HEC-RAS (see **Section 3**), however detailed layout proposals will need to be confirmed once the proposed diversion of the upper Boverton Brook is designed. Consequently, housing units will be located at elevations above the 0.1% AEP flood event + blockage flood levels along the Boverton Brook – i.e. entirely in Flood Zone A. Total area of 4.5 ha (all greenfield at present), see St Athan drainage masterplan in **Appendix C**. Therefore the only further flood risk requirement for this site will be a SWDS, required in order to demonstrate how surface water will be managed by the development in order to prevent an increase in downstream flood risk. It is proposed to use a combination of SuDS, comprising source control (underground storage and infiltration) and site control (attenuation basins). Details of the drainage proposals for this component can be found in **Section 4** and the DTC St Athan - Surface Water Management Strategy (**Appendix C**).

North of West Camp – Figure 2.2 and Table 2.4

It is planned to place 55 housing units on the North of West Camp site. The south-eastern edge of this area is adjacent to the Boverton Brook. This watercourse has been modelled in HEC-RAS (see **Section 3**) and the model outputs used to inform site layout. Consequently, housing units will be located at elevations above the 0.1% AEP flood event + blockage flood levels along the Boverton Brook – i.e. entirely in Flood Zone A. Total area of 3 ha (all greenfield at present), see St Athan drainage masterplan in **Appendix C**. Therefore the only further flood risk requirement for this site will be a SWDS, required in order to demonstrate how surface water will be managed by the development in order to prevent an increase in downstream flood risk. It is proposed to use a combination of SuDS, comprising source control (underground storage and infiltration) and site control (attenuation basins). Details of the drainage proposals for this component can be found in **Section 4** and the DTC St Athan - Surface Water Management Strategy (**Appendix C**).

Castleton (golf course / stadium) – Figure 2.2 and Table 2.4

It is planned to place 172 housing units on golf course/stadium site. The entire site is in Flood Zone A, well away from any nearby watercourses. Total area of 7 ha (mixture of greenfield/brownfield), see St Athan drainage masterplan in **Appendix C**. Therefore the only

further flood risk requirement for this site will be a SWDS, required in order to demonstrate how surface water will be managed by the development in order to prevent an increase in downstream flood risk. It is proposed to use a combination of SuDS, comprising source control (underground storage and infiltration) and site control (attenuation basins). Details of the drainage proposals for this component can be found in **Section 4** and the DTC St Athan - Surface Water Management Strategy (**Appendix C**).

Table 2.4 Service Families Accommodation – TAN15 summary

Development	TAN15 Flood Zone	TAN15 Justification Test Met?	Further Investigation
SFA – Tremains Farm	Flood Zone A and C2	Majority of site appears to be located within the lowest risk TAN-15 flood zone. More detailed investigation required for areas adjacent to Boverton/Llanmaes Brooks to delineate areas of Flood Zone C2. Residential development will only occur in TAN15 Flood Zone A.	SWDS required. See Appendix C . For flood modelling, see section 3 of this report.
SFA – Picketston South West	Flood Zone A and C2	Majority of site appears to be located within the lowest risk TAN-15 flood zone. More detailed investigation required for areas adjacent to the upper Boverton Brook ditch-course. Residential development will only occur in TAN15 Flood Zone A.	SWDS required. See Appendix C . It is proposed to divert this upper part of the Boverton Brook to a new course. Proposals for diversion to be developed and agreed with the EAW.
SFA – North of West Camp	Flood Zone A and C2	Majority of site appears to be located within the lowest risk TAN15 flood zone. More detailed investigation required for areas adjacent to Boverton Brook to delineate areas of Flood Zone C2. Residential development will only occur in TAN15 Flood Zone A.	SWDS required. See Appendix C . For flood modelling, see section 3 of this report.
SFA – Castleton (golf course/stadium)	Flood Zone A	Yes – located within the lowest risk TAN15 flood zone.	SWDS required. See Appendix C .

The TAN15 flood map (**Figure 3.2**) only indicates limited areas of Flood Zone B (geological indicators of flooding), located outside of these development areas.

2.2.4 Field Training Area

A Field Training Area (FTA) is proposed for land at Castleton (**Figure 2.2** and **Table 2.5**). This area will generally remain as greenfield as at present (i.e. grassed areas/shrubs), with only limited development (access track, small areas of hardstanding associated with training structures).

Table 2.5 Field Training Area – TAN15 summary

Development	TAN15 Flood Zone	TAN15 Justification Test Met?	Further Investigation
Field Training Area	Flood Zone A	Yes – located within the lowest risk TAN15 flood zone.	No further investigation.

The TAN15 flood map (**Figure 3.2**) only indicates limited areas of Flood Zone B (geological indicators of flooding), located outside of this development area.

2.2.5 Associated road improvements

Northern Access Road (NAR) – Figure 2.2 and Table 2.6

The new Northern Access Road (NAR) will run from the B4265 0.5 km northwest of the existing Boverton Junction (GR: SS 982 688) and run roughly parallel between 400m to 200m northwest of the course of the existing access road before joining with it at Picketston. From here the existing road will be improved eastwards to Eglwys Brewis. New junctions will be provided along the route for access to the Llanmaes Road and to tie in with the old Boverton road at Picketston. Access junctions will be formed for the ABP North entrance, the DTC Picketston site, and the Red Dragon Hangar, alongside an improved junction with the Picketston House road, and at Eglwys Brewis an improved DTC East Camp site entrance plus an access to a proposed museum. New access points will be provided from the NAR to the western three SFA sites.

The main watercourse crossings that will be required are:

1. Llanmaes Brook at (GR: SS 985 689) – 60m span high-level bridge (soffit level to be 600mm above the 0.1% AEP flood level). This watercourse is Environment Agency Wales Main River; and
2. Boverton Brook at Picketston (GR: SS 995 692) – pipe culvert. The catchment area here is 1.5km² and the watercourse is an Ordinary Watercourse; and
3. Minor field drains (i.e. GR: SS 994 692).

The existing ditch-course that forms the upper Nant y Stepsau is overgrown, partially blocked and silted. The watercourse does not appear to have been maintained over a long period of time, as evidenced by the frequent standing water on this section of the existing road. The existing ditch-course will be reinstated as a series of attenuation basins and swales, running eastwards north of the NAR; outlets from these will discharge to the Nant y Stepsau watercourse east of the Picketston Road (GR: ST 003 693). The outlets will be located within existing highway land and will replace the existing Picketston House road bridge. The proposed feature layout is shown in the DTC St Athan SWDS (see Proposed Drainage Strategy drawing within) located in **Appendix C**.

Downstream of this bridge, no modifications are proposed to the Main River section of the Nant y Stepsau watercourse (except, if necessary the two other road crossings before the Nant y Stepsau joins the River Thaw). These are located at GR: ST 009 695 and GR: ST 011 699. However, flows discharging will be at greenfield ensuring that flood flows are not exacerbated, and the potential for scour is not increased.

In drainage terms the improvements to the NAR form three distinct units:

- The NAR south of the Llanmaes Brook to the B4265 – area 0.96ha (proposed to drain to the Boverton Brook south of the Railway Embankment, GR: SS 985 686);
- The NAR north of the Llanmaes Brook to Picketston – area 2.50ha (proposed to drain to the Boverton Brook adjacent to the Carpenters Arms PH, GR: SS 994 692);
- Improvements to existing road corridor from Picketston to Eglwys Brewis – area 2.24ha (proposed discharge adjacent to Picketston House road bridge, GR: ST 003 693)

Section 4 and **Appendix C** detail the Surface Water Drainage Strategy. A detailed layout plan is provided in **Appendix C** - see the 'Overall WAG Drainage Strategy' figure.

Southern access road – Figure 2.2 and Table 2.6

Construction of the southern access road will involve the forming of a new section of carriageway parallel to the B4265 in order to incorporate a new signal controlled junction (GR: ST 003 675). A new bridge will also be provided across the railway line. A junction to link with the old St Athan road will be provided, with the new access road continuing to the entrance of the ABP South.

The construction of this access road does not involve the crossing of any watercourses. **Section 4** and **Appendix C** detail the Surface Water Drainage Strategy. A detailed layout plan is provided in **Appendix C** - see the 'Overall WAG Drainage Strategy' figure.

Various improvements to the B4265 and A4226/B4226:

St Athan Road Junction (GR: ST 017 675) - Figure 2.1 and 2.2 and Table 2.6

Minor road widening, some new pavements and a new bus stop bay. Located in TAN15 Flood Zone A. **Section 4** and **Appendix C** detail the Surface Water Drainage Strategy.

Gileston Old Mill (GR: ST 028 676) - Figure 2.1 and 2.2 and Table 2.6

Small road improvements: construction of 200m of straightened carriageway south of existing kink in road, immediately to the west of the River Thaw road bridge. Construction of visibility splays east of the River Thaw. Road drainage from the new section of carriageway will be routed to River Thaw. Located in TAN15 Flood Zone A. **Section 4** and **Appendix C** detail the Surface Water Drainage Strategy.

Waycock Cross (GR: ST 017 675) - Figure 2.1 and 2.2 and Table 2.6

Improvements here will involve the construction of a replacement controlled junction for the A4266/B4266 junction. This will be constructed north of the existing roundabout, with a new section of the A4266 to the east in order to replace the existing section of road, which will remain as a separate access to the existing residential properties, but set back from the replacement roundabout's access carriageways. An attenuation feature will be provided in the centre of the roundabout, draining to the River Waycock, which is located 1km to the north. Located in TAN15 Flood Zone A. **Section 4** and **Appendix C** detail the Surface Water Drainage Strategy.

Table 2.6 Associated Road Improvements – TAN15 summary

Development	TAN15 Flood Zone	TAN15 Justification Test Met?	Further Investigation
NAR	Flood Zone A and C2	Majority of route is located in the lowest risk TAN15 flood zone. More detailed investigation required for areas adjacent to Boverton/Llanmaes Brooks to delineate areas of Flood Zone C2. Road will be placed in Flood Zone A with a high wide-span bridge across the Llanmaes Brook and its floodplain.	SWDS required. See Appendix C . For flood modelling, see section 3 of this report.
SAR	Flood Zone A	Yes – located within the lowest risk TAN15 flood zone.	SWDS required. See Appendix C .
St Athan Road Junction	Flood Zone A	Yes – located within the lowest risk TAN15 flood zone.	SWDS required. See Appendix C .
Gileston to Oldmill	Flood Zone A and C1 / C2	Majority of route appears to be located within the lowest risk TAN15 flood zone. Minor land take within a tidally defended area (Flood Zone C1 / C2).	SWDS required. See Appendix C . Confirm acceptability of improved route impinging on area of tidal flood risk.
Waycock Cross	Flood Zone A	Yes – located within the lowest risk TAN15 flood zone.	SWDS required. See Appendix C .

The TAN15 flood map (**Figure 3.2**) only indicates limited areas of Flood Zone B (geological indicators of flooding), located outside of these development areas.

2.2.6 New rising foul main to Llantwit Major WwTW.

This has been classed as permitted development, and has therefore not been included within the scope of this FCA, but is included in the EIA. The site of the Llantwit Major WwTW (GR: SS 954 694) is in TAN15 Flood Zone A (less than 0.1% probability of flooding from fluvial/tidal sources in a given year). The route of the proposed rising main is almost entirely in Flood Zone A, except for at four watercourse crossings: the Nant y Stepsau ditch (GR: SS 999 692), the Boverton Brook ditch at Picketston (GR: SS 995 692), and the Llanmaes Brook (GR: SS 984 690) adjacent to the St Athan site, and further west the Odney Brook at Purlon Farm 500m east of the WwTW (GR: SS 960 694). These represent four perpendicular crossings of areas of TAN15 Flood Zone C2. Details are provided in **Table 2.7**.

The volume of foul flows to the Aberthaw WwTW will not be altered, therefore no works to this foul pipeline or works are proposed.

Table 2.7 Llantwit Major WwTW and rising foul main – TAN15 summary

Development	TAN15 Flood Zone	TAN15 Justification Test Met?	Further Investigation
WwTW	Flood Zone A	Yes – located within the lowest risk TAN15 flood zone. N.B. Existing development.	None.
Rising Foul Main	Flood Zone A with four crossings of watercourses and associated Flood Zone C2.	Yes – passage of utilities such as a foul main is permitted through Flood Zone C2.	Permitted development, DCWW and contractor to liaise with EAW.

The TAN15 flood map (**Figure 3.2**) only indicates limited areas of Flood Zone B (geological indicators of flooding), located outside of development areas.

2.3 Access

Access and egress of the site is possible at times of flood (i.e. avoiding areas of Flood Zone C1 or C2) through St Athan to the B4265 (high level bridge across the Rhyl Stream, or alternative route via old Llantwit Road to Batslays, and then the link to the B4265). From the south of the site the site the B4265 can be accessed via the old Llantwit Road. The old Llantwit Road also provides a route northwards to Eagle Road and towards Eglwys Brewis, avoiding potential flooding around the Boverton junction of the B4265. East of the site the B4265 crosses the River Thaw on a high-level bridge which is likely to remain operational even at times of flood. There are also various routes northwards from the site beyond Picketston, which can be used to access Llantwit Major. The proposed NAR will reinforce access to the B4265 west of the St Athan site.

3. Flood Consequence Assessment

3.1 Sources of Flood Risk

Based on the initial assessment and consultations (**Section 1**), and the proposed development as set out in **Section 2**, **Table 3.1** details the key sources of flood risk at the St Athan site. Apart from surface water flood risk, the key risk is from fluvial flooding associated with the small watercourses adjacent to the site. Flood risk from these sources is discussed further in **Section 3.3**.

Table 3.1 Potential Sources of Flooding

Flooding Source	Risk Identified	Source	Pathway
Fluvial	Yes	Boverton Brook, Llanmaes Brook, Nant y Stepsau and Rhyl Stream.	From watercourse to adjacent low lying parts of the site.
Tidal	No	-	-
Groundwater	Potentially	Aquifers beneath site	Into lower levels of buildings on low lying parts of the site.
Sewers	Potentially	Foul Water Sewer	Exceedance from Sewer System
Surface Water Run On	Potential	Upslope areas adjacent to development (principally from high land at Picketston or Llanmaes). Additional risk on site due to extensive size of the site.	Overland flow
Surface Water Runoff	Potential	Development's Surface Water Drainage	Hardstandings, highways and surface water drainage system
Reservoirs, Canals and Other Artificial Surfaces	No reservoirs or canals near site. One Flood Alleviation Scheme (FAS).	Potential for failure of the Llanmaes FAS a small flood retention dam. Risk is considered to be minimal due to regular inspection/appropriate maintenance by the Environment Agency.	Inundation of area downstream.

Summary of identified flood risks

Fluvial flood risk has been identified as the main flood risk to the site and is discussed further in **Section 3.2**. This section identifies where more detailed investigations are required, which are then laid out in **Section 3.3**. **Section 3.4** covers the remaining flood risks to the site. **Section 4** covers surface water management for the site, and sets out the criteria for each element of the development's Surface Water Drainage Strategy (SWDS).

3.2 Sources of Fluvial Flood Risk

Hydrological features (local watercourses, catchments, gauging station and groundwater monitoring borehole) adjacent to the planning application boundary are shown in **Figure 3.1**. The locations of the proposed development areas are overlain on top of the WAG TAN15 flood map in **Figure 3.2**. **Figure 3.3** shows the Environment Agency's flood map.

The TAN15 Flood Zones are defined as follows: -

- **Flood Zone A** – areas considered to be at little or no risk of fluvial or tidal/coastal flooding (less than 0.1% probability and no geological indicators of flooding). Used to indicate that the justification test is not applicable and no need to consider flood risk further;
- **Flood Zone B** – areas known to have been flooded in the past evidenced by sedimentary deposits. Used as part of the precautionary approach to indicate where site levels should be checked against the extreme (0.1%) flood level. If site levels are greater than the flood levels used to define the adjacent extreme flood outline there is no need to consider flood risk further;
- **Flood Zone C** – based on Environment Agency extreme flood outline, equal to or greater than 0.1% (river, tidal or coastal). Used to indicate that flooding issues should be considered as an integral part of decision making by the application of the justification test including assessment of consequences.

Flood Zone C is subdivided into:

- **Flood Zone C1** – areas of the floodplain which are developed and served by significant infrastructure, including flood defences. Used to indicate that development can take place subject to application of the justification test including assessment of consequences;
- **Flood Zone C2** – areas of the floodplain without significant flood defence infrastructure. Used to indicate that only less vulnerable development should be considered subject to application of the of justification test, including acceptability of consequences. Emergency services and highly vulnerable development should not be considered.

The Environment Agency flood map shows two flood zones:

- The 1% AEP Flood Zone indicates land at high risk of flooding.
- The 0.1% AEP Flood Zone (equivalent to TAN15 Flood Zone C2) shows land at risk from an extreme flood event.

Comparison of the Environment Agency flood map with the TAN15 flood map indicates that there are some differences in the extents of the 0.1% flood extent. This is due to the Environment Agency map being based on the most up to date flood information, whilst the TAN15 flood maps were published in 2004. Updated WAG TAN15 maps are due to be issued in the near future, but were unavailable during the timescales of this study. The updated TAN15 flood maps will be based on the latest Environment Agency flood mapping (i.e. **Figure 3.3**), and so will resolve the discrepancy noted above. It should be remembered that the Environment Agency's flood map (and Flood Zone C on the TAN15 map) covers the whole of England and Wales, and for the smaller watercourses is based on relatively coarse topographic survey data.

Consequently, whilst indicative, their utility for accurate evaluation of flood risk at the site scale is limited and further detailed site assessment is necessary to confirm the specific risk to individual sites. The Environment Agency's flood map does not generally cover the catchments of smaller watercourses, such that the extents of flooding on the upper reaches of the main watercourses at St Athan are not indicated on the maps.

Proposed Development in Relation to Fluvial Flood Risk

The overall St Athan site covers a total area of approximately 293ha at the base and an adjacent 160ha, although individual developments are limited to specific areas within these figures. Elevations range from around 30 to 40m AOD at the edge of the Boverton, Rhyl and Nant y Stepsau valleys, to just above 50m AOD in the centre of West Camp, and on the eastern edge of East Camp. The central site (West Camp, RDH and East Camp and the proposed ABP sites) is located on a relatively flat plateau area, and is surrounded by (and drained by) three watercourses: the Boverton Brook to the northwest and west, the Nant y Stepsau to the north and northeast, and the Rhyl stream to the southeast. The central area of the site, north of the B4265 and within the perimeter road is located in TAN15 Flood Zone A.

To the north of the main site is the Picketston site which rises up from the Nant y Stepsau and contains the headwaters of the Boverton Brook (elevations 40m to 55m AOD). To the west of the main site are the proposed sites of the Tremains Farm, Picketston South West and North of West Camp SFA sites (elevations 34m to 46m and 39m to 45m AOD respectively). These are all located in TAN15 Flood Zone A, with strips of Flood Zone C2 running along the respective adjacent watercourses. The Castleton SFA site and the ETA are located east of the main site at elevations between 43m to 52m and 25m to 43m AOD respectively. These two areas are in TAN15 Flood Zone A.

In terms of areas of Flood Zone C2 adjacent to the courses of the Boverton Brook (**Appendix B**, Plates B1 to B41), Llanmaes Brook (**Appendix B**, Plates B42 to B44), Nant y Stepsau (**Appendix B**, Plates B45 to B57) and the Rhyl Stream (**Appendix B**, Plates B58 to B63) watercourses, the following concerns need to be considered:

- The Rhyl Stream is set in a valley, and no development is proposed adjacent to or crossing this watercourse. Beyond an appropriate SWDS for the areas of the proposed development that drain to this watercourse it is not considered further in this FCA.
- The Boverton Brook rises within the Picketston area to the north of the main site, flowing southwestwards alongside of the western perimeter road (the Boverton to Eglwys Brewis road). Several areas of proposed development are located adjacent to this watercourse: the Tremains Farm, Picketston South West and North of West Camp SFA sites and the Picketston component of the DTC. Hydraulic modelling has therefore been carried out to delineate the edge of Flood Zone C2 (0.1% probability in a given year) including for blockages to key structures. This will allow for the SFA developments to be located entirely in Flood Zone A. The situation at Picketston is more complicated, here the watercourse is relatively small in size and it is proposed to divert the watercourse in order to accommodate the development proposed here. This is discussed in more detail in **Section 3.3.1**. A SWDS will be required for the areas of the proposed development that drain to this watercourse.
- The Llanmaes Brook rises to the west of the site, and joins the Boverton Brook 200m upstream of the railway embankment. It is to be crossed by the Northern Access Road (NAR), and passes along the northern edge of the Tremains Farm SFA site. Hydraulic

modelling has therefore been carried out to delineate the edge of Flood Zone C2 (0.1% probability in a given year) including for a blockage to the Llanmaes FAS. The road bridge's abutments and adjacent SFA development will be set back outside of this flood zone.

- The Nant y Stepsau rises at Picketston adjacent to the Boverton-Eglwys Brewis road, initially as a poorly defined roadside ditch adjacent to the Boverton Brook, before flowing eastwards. The ditch is severely silted and overgrown. Standing water is frequently present on the existing road associated with the poor capacity of this ditch. The proposed NAR ties in with the existing Boverton-Eglwys Brewis Road at this point. Several areas of proposed development are located adjacent to this watercourse: the improved NAR and associated junctions and the southern edge of the Picketston component of the DTC. At present hydraulic modelling has not been carried out to delineate the edge of Flood Zone C2 (0.1% probability of flooding in a given year). However given the small size of the catchment, and that the watercourse runs to the east in a shallow valley, it is considered to be localised to the adjacent corridor only. It is considered that as the proposed road alterations for the NAR, represent improvements to an existing road detailed hydraulic modelling will not be required. It is proposed to carry out works to reinstate the ditch-course along the north side of the NAR within the Picketston DTC site as a chain of swales/attenuation basins. SWDSs will be required for the areas of the proposed development that drain to this watercourse.

Downstream of the site the Boverton and Llanmaes Brooks form the Hoddnant, which flows through Boverton and then south of Llantwit Major to the sea. The Nant y Stepsau and Rhyl stream flow westwards and join the River Thaw, which flows south to the sea. The main St Athan site effectively forms a watershed between the small upper catchments of several watercourses. The size of catchments indicated by FEH is shown in **Table 3.2** below. It should be noted that the existing artificial drainage systems on site do not completely match these catchments; **Figure 4.2** shows a more representative analysis of the catchment divides. At present (and upon redevelopment) the Red Dragon Hangar area drains to the Nant y Stepsau, and the existing East Camp site to the Rhyl Stream, whilst the topographical/FEH catchment divide runs through these areas.

Table 3.2 Key Catchment Parameters

Catchment	Catchment size from FEH (km ²)
Rhyl Stream - ST 015 683 - (St Athan road bridge) Source at ST 007 681	1.63
Boverton Brook - SS 994 692 - (Carpenters Arms PH) Source at SS 995 694	1.64
Boverton Brook- SS 986 687 - (U/S junction with Llanmaes Brook)	2.78
Boverton Brook- SS 984 686 - (B4265 road bridge)	8.45
Llanmaes Brook - SS 985 689 - (U/S of proposed NAR bridge) Source at: SS 966 703	5.30
Llanmaes Brook - SS 986 687 - (junction with Boverton Brook)	5.33

Nant y Stepsau - **ST 003 693** - (Picketston House road bridge)

1.42

Source at: SS 999 692

3.3 Detailed Investigation of Fluvial Flood Risk

The Rhyl Stream was scoped out of further assessment in **Section 3.2**, since no development is proposed within St Johns Valley, where this watercourse issues. **Section 3.3.1** details the hydraulic modelling carried out with respect to the Boverton and Llanmaes Brooks, whilst **Section 3.3.2** details the assessments carried out with regards to development adjacent to the Nant y Stepsau.

3.3.1 Boverton and Llanmaes Brooks

The TAN15 and Environment Agency flood maps (**Figure 3.2** and **3.3**) provide an indication of the degree of flood risk along these watercourses. In order to more accurately quantify flood extents and therefore flood risk, a HEC-RAS model has been constructed. Two key scenarios have been modelled, the 0.1% AEP flood extent and the 0.1% AEP with an 85% blockage of key structures (the bridge at Froglands Farm, the railway culvert and the Llanmaes FAS). It is the extent of the 0.1% AEP flood that defines the Flood Zone C2. In support of these extents, the extents of the 20%, 5%, 2%, 1%, 1% +CC have been calculated to verify the accuracy of the modelling, these specific events being requested by the Environment Agency Wales.

The channel south of the Boverton to Eglwys Brewis Road (GR: SS 995 692) is Main River, with the ditch-course to the north within the Picketston area being Ordinary Watercourse. The hydraulic model comprises topographically surveyed channel cross sections, plus details of all in-channel structures along the reach (i.e. bridges, culverts and embankments), which may act to restrict flows and increase flood levels. Elevations of the general floodplain areas and valley sides have been derived from aerially surveyed LIDAR elevation data purchased from the Environment Agency.

Environment Agency 2001 – Boverton Brook Hydrology Investigation

The Environment Agency has provided a copy of their 2001 investigation into the Boverton Brook catchment's hydrology, containing summary information of investigations carried out. The report indicates that the use of standard FEH catchment descriptors to estimate flood events on the Boverton Brook underestimates flood peaks in the catchment. This is because flood peaks up to the 1% AEP event, estimated using the basic catchment descriptors are well below the known 4.5m³/s capacity of the culvert in Boverton village. Since flooding associated with the culvert's capacity being exceeded caused flooding in 1998, 1999, 2000 and most recently in September 2008, a shorter return period for this type of flood event would be expected. Flood estimation from the basic FEH descriptors is therefore suspect.

FEH recommends that wherever possible the catchment descriptors should be checked, and if necessary revised against more detailed catchment information. This can include flow gauging in the catchment itself, and/or the use of pooled information from other similar catchments that have been gauged. In addition the selection process by which the WinFap¹ FEH software pools information from similar catchments requires confidence in three catchment descriptors: SAAR, AREA and BFI (Standard Average Annual Rainfall, Area and the Base Flow Index). The pooled analysis approach therefore requires confidence in these three values. In particular the BFI and related SPR (Standard Percentage Runoff) values are important for assessing how

¹ WinFap FEH is a software package developed by CEH-Wallingford to estimate flood peaks

responsive the catchment is to rainfall events. The values provided for SPR and BFI on the FEH CD (BFIHOST and SPRHOST) are derived from the national HOST (Hydrology of Soil Types) classifications of how soils typically respond to rainfall events, rather than local catchment measurements. These values therefore have been re-evaluated.

In terms of catchment data a flow gauging station (monitoring levels) was installed in the Boverton Brook immediately downstream of the B4265 culvert in the summer of 2000. Rainfall records are also available for a raingauge at Llantwit Major from 1999 onwards and for Schwyll near Bridgend from 1992. All fo these gauges record data at 15 minute intervals. This data can therefore be used to revise the catchment descriptors and to provide an updated estimate of the various flood events of interest.

When the Environment Agency's previous investigation was carried out only limited data (less than 1 year) was available for the catchment, and in addition the Llantwit Major rainfall record was relatively short. This meant that QMED could not be estimated directly from the gauged flow records. Use of a QMED derived from the catchment descriptors ($0.8 \text{ m}^3/\text{s}$) and a growth curve derived in WinFap FEH, using a pooling group selected based on FEH catchment descriptors gave a Q100 value of $1.9 \text{ m}^3/\text{s}$ – a value well below the culvert's capacity. FEH advises that wherever possible catchment data should be used to inform the estimation of QMED derived in this way wherever possible, and suggests that gauged flow data from a catchment geographically close and hydrologically similar should be sought. Therefore the next step utilised a 'donor' QMED value derived from historic flow records of two geographically close gauged catchments (the Ewenny at Keeper's Lodge, Bridgend and the Ritec in Pembrokeshire). This gave a QMED value of $1.9 \text{ m}^3/\text{s}$ and a Q100 value of $4.5 \text{ m}^3/\text{s}$, the latter value is the culvert's capacity, but as the culvert's capacity was exceeded 3 times in 3 years the return period for this flood event should be shorter (i.e. more frequent) than 100 years on average).

These two standard FEH methods were therefore considered unsuitable and a more detailed investigation of the catchment descriptors was undertaken. A model was produced to simulate the catchments response to rainfall, and from this to estimate the percentage runoff from the catchment. Percentage runoff was found to be between 40 and 50% (compared to a range of 15 to 20% when estimated theoretically). As the two methods used by the Environment Agency above did not provide suitable estimates, three further methods were used in the Environment Agency's 2001 report to estimate QMED:

3. Re-assess the catchment descriptors based on the gauged flow/rainfall data;
4. Using the Flood Studies Report (FSR) rainfall-runoff method; and
5. Using historic rainfall data to derive historic peak flows and to thereby estimate QMED based on the flood peaks produced.

The revised catchment descriptors derived in part 1 of this process support the analysis undertaken in parts 2 and 3.

For method 1 SPRHOST was adjusted from 11.7% (FEH CD value) to an SPR of 31.7%, based on the investigations into percentage runoff undertaken, which indicated a higher level of percentage runoff. No further details of the estimation/conversion used to obtain 31.7% are given. It is presumed that the procedure outlined in the FEH Volume 4, Appendix A.5 and A.5 was used. As the WinFAP FEH report uses SAAR, AREA and BFI to derive similar catchments for the pooled analysis, the following equation rearranged from FEH (equation 2.16,

volume 4, p28) was used to convert the updated SPR value into an updated BFI value. The updated BFI value is not stated in the report.

$$\text{BFI} = (72 - \text{SPR}) / 66.5$$

A new QMED value of 2.4m³/s was derived from these updated catchment descriptors. A further pooled analysis was then undertaken to identify an updated growth curve for the catchment based on the updated BFI value.

Method 2 involved using these updated catchment descriptors in the FSR rainfall runoff method. Percentage runoffs based on an SPR value of 31.7%. A critical duration of 12 ¼ hrs was identified. A value for QMED is not given.

Method 3 involved using the longer length of rainfall record available from the Schwyll catchment to artificially derive an 8 year long time series of flood peaks over threshold. FEH (volume 3, p8) provides a method for deriving QMED from these peaks using the following equation:

$$\text{QMED} = wQ_i + (1-w)Q_{i+1}$$

Where (for an 8 year long record), $w = 0.147$ and Q_i and Q_{i+1} are the 6th and 7th largest events in the record. Using this method QMED was estimated as 2.73m³/s.

Table 3.3 Environment Agency 2001 Report - Methods Used to Estimate Flood Magnitude on the Boverton Brook

Method	QMED estimate (m ³ /s)	Q100 estimate (m ³ /s)
1) Catchment descriptors used to estimate QMED. Pooled analysis to obtain growth curve.	0.8	1.9
2) Donor QMED from geographically close catchments. Pooled analysis to obtain growth curve.	1.9	4.5
3) Updated catchment descriptors used to estimate QMED. Pooled analysis based to identify a growth curve derived from these updated catchment descriptors.	2.4	7.9
4) FSR rainfall-runoff method	-	8.0
5) QMED derived from peaks over threshold analysis. Growth curve derived in 3) used.	2.73	8.9

The values produced for by methods 3, 4 and 5 were felt to be the best appropriate estimates of the catchments flood hydrology. Some further modifications were made to these estimates in order to account for the impact of flood storage facility recently constructed in the upper catchment. A value of 8.0m³/s was taken forward as the Q100.

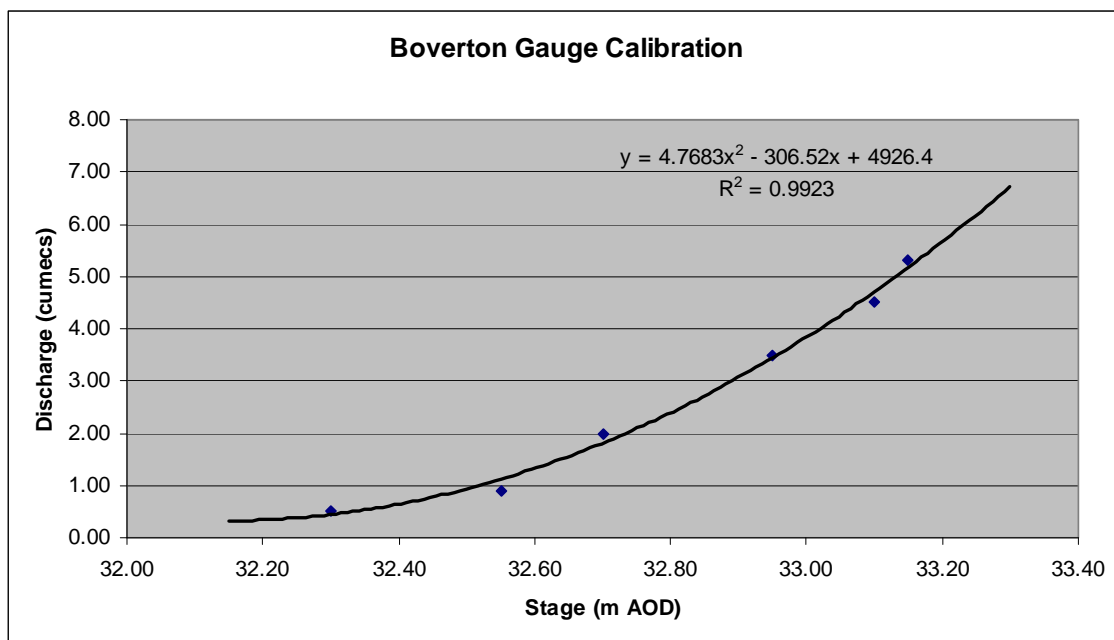
As the Environment Agency's investigation is now 8 years old, there is now a larger record of rainfall and flows at Boverton. In addition the methodologies originally used have been updated. For instance the FSR-FEH rainfall runoff method was restated as the ReFH in 2006

and WinFAP FEH version 2 was released in 2007. The algorithms with both have been updated where appropriate based on newer data and statistical techniques. In particular WinFap FEH version 2 makes use of a larger data set of peak flood events. The Environment Agency has therefore requested that the investigations in the report are revisited in order to verify the estimation of QMED and the growth curves used to derive the various flood events.

Updated Catchment Hydrology

No detailed stage to flow calibration curve is held by the Environment Agency for the Boverton gauge. Therefore the relationship between the stage and flood peaks in Figures 3 and 4 of their 2001 report were utilised to identify the stage-discharge relationship. Several additional values for low flows were derived by calibrating a HEC-RAS model to reproduce these known discharge-stage points. Using this calibration (shown in **Figure 3.4**) the recorded flood levels were converted to flow values.

Figure 3.4 Boverton Brook Gauge Calibration



Following the procedures outlined in Appendix A.4 of FEH volume 4, the percentage runoff was derived for the eleven largest flood events on record in the time series of data. One event was discarded due to apparent errors in the recording of levels (prolonged flat flood peak followed by a vertical drop to baseflow level). Following this the procedures outlined in Appendix A.6 of FEH volume 4, were used to incorporate the effects of antecedent rainfall over the preceding 5 days on catchment runoff. For 10 of the events the best match was found between the Llantwit Major rain gauge hyetograph and the Boverton flood hydrograph, however for one event (12-02-2001) these peaks did not match. However, for this event a good match was found between the Boverton flood hydrograph and the Schwyll rain gauge hyetograph. It should be remembered that the rainfall recorded at the point location of the rainfall gauges may not be representative of what is happening across the Boverton Brook catchment, since any given rainfall event will vary considerable across time and space. Nonetheless, the Llantwit Major rain gauge does 10 times out of 11 provide a good correlation between hyetograph peak

and the Boverton flow gauge's hydrograph peak. Revised SPR values for each flood event were then calculated. A revised BFI was also calculated based on the equation relating SPR to BFI detailed above. Details of the events and new values of QMED, SPR and BFI are presented in **Table 3.4**.

Table 3.4 Historic Event Analysis – Derived values of QMED from Peaks over Threshold and SPR and BFI values

Rank	Date	Stage (m AOD)	Peak Discharge (m ³ /s)	SPR
1	30-10-2000	33.17	5.44	40.3
2	04-09-2008	33.14	5.11	56.3
3	01-01-2003	33.01	4.02	59.3
4	12-08-2004	32.96	3.59	25
5	23-01-2009	32.96	3.59	60.1
6	02-08-2007	32.93	3.36	20.9
7	12-02-2001**	32.92	3.28	59.5
8	06-11-2002	32.90	3.17	*
9	12-10-2000	32.89	3.09	32.3
10	03-11-2000	32.89	3.09	46
11	26-02-2002	32.87	2.93	49.3
			QMED	3.3
			SPR	44.9
			BFI[†]	0.408

*Not included due to error in hydrograph, stage recorder appears to have stuck shortly after the flood peak was reached, remaining horizontal just below the level of the flood peak for a prolonged period before dropping vertically back to lower flow levels.

**No match between flood hydrograph and rainfall at the Llantwit Major gauge. Good match with rainfall recorded at the Schwyll gauge.

[†]Calculated from derived SPR value

A clear trend can be seen with winter events tending to result in SPRs between 40 and 60%, whilst the two summer events have markedly lower SPRs. Based on the peak flood event discharges calculated in **Table 3.4**, QMED was estimated based on the following equation (FEH volume 3, p8):

$$\text{QMED} = wQ_i + (1-w)Q_{i+1}$$

In this record there are 8 complete hydrological years (October 2000 through to September 2008). Therefore for an 8 year long record, $w = 0.147$ and Q_i and Q_{i+1} are the 6th and 7th largest events in the record. Using this method QMED was estimated as $3.3\text{m}^3/\text{s}$.

FEH also provides a method for deriving QMED based on catchment descriptors, using the updated catchment descriptors (SPR and BFI), the equation is:

$$\text{QMED}_{\text{rural}} = 1.172 * \text{Area}^{\text{AE}*} (\text{SAAR}/1000)^{1.560*} \text{FARL}^{2.642*} (\text{SPR}/100)^{1.211*} 0.0198^{\text{RESHOST}}$$

Where:

$$\text{AE} = 1 - (0.015 \text{Ln}(\text{AREA}/0.5))$$

$$\text{RESHOST} = \text{BFI} + 1.3(\text{SPR}/100) - 0.987$$

and $\text{AREA} = 8.45$, $\text{FARL} = 1$, $\text{SAAR} = 1016$.

This gives a QMED value of $3.4\text{m}^3/\text{s}$. However, the previous QMED method which derives QMED using Peaks over Threshold data is preferred, since it makes use of the actual Boverton Brook catchments historic flood peaks.

Using these updated values of QMED and BFI (alongside the above values of AREA and SAAR) a pooling group was identified in WinFAP FEH. This pooling group is detailed in **Table 3.5** below, and consisted of 523 years of records.

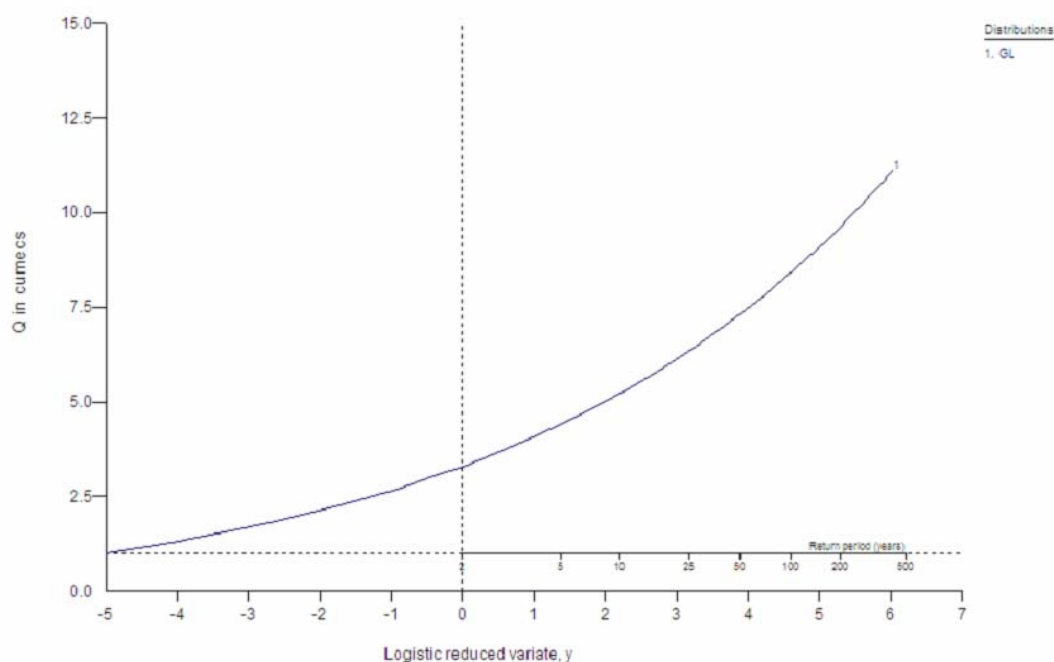
Table 3.5 WinFap FEH Pooling Group

Catchment	Years
203046 Rathmore Burn @ Rathmore Bridge	25
27010 Hodge Beck @ Bransdale Weir	41
50009 Lew @ Norley Bridge	17
203049 Clady @ Clady Bridge	24
28033 Dove @ Hollinsclough	27
72014 Conder @ Glagate	39
27051 Crimple @ Burn Bridge	34
22003 Usway Burn @ Shillmoor	25
41020 Bevern Stream @ Clappers Bridge	37
25019 Leven @ Easeby	28
28041 Hamps @ Waterhouses	21
47018 Thrushel @ Hayne Bridge	18
203042 Crumlin @ Cidercourt Bridge	27
24006 Rockhope Burn @ Eastgate	20
54025 Dulas @ Rhos-y-petrel	37

205005 Ravernet @ Ravernet	34
41022 Lod @ Halfway Bridge	33
84009 Netham @ Kirkmuirhill	36
Total Years	523

For a pooling group of this size it is recommended that any sites with a discordancy value above 3 are checked for possible discordancy. Only the Lew had a value slightly above this (3.142). FEH procedures suggest the discordancy should be investigated, however on review the annual maxima series was found to be acceptable and left within the pooling group. The growth curve is shown in **Figure 3.5**.

Figure 3.5 WinFAP FEH derived growth curve for the Boverton Brook



The growth curve and QMED values were used to obtain peak flows for the 20%, 5%, 2% and 1% AEP event peak flows.

The current procedure recommended by the Environment Agency for calculating the 0.1% AEP peak flood involves running the ReFH spreadsheet package utilising the same updated catchments descriptors to estimate the 1% AEP event and the 0.1% AEP event. The ratio between these two is then calculated; this ratio is then applied to the 1% AEP event as calculated in WinFAP FEH to obtain the 0.1% AEP event (this is detailed below). This approach is preferred since the WinFAP FEH process is calibrated against a larger pool of flood

data compared to the ReFH method, but not is recommended for estimating very large return period floods.

- ReFH 1% AEP peak flow estimate = 13.9m³/s
- ReFH 0.1% AEP peak flow estimate = 23.9m³/s
- Ratio: 1.72

The 1% AEP plus climate change allowance flow is calculated by multiplying the 1% AEP event by 1.2 to represent a 20% increase in flows due to climate change.

The resulting flows are shown in **Table 3.6**.

Table 3.6 Flood Return Periods and Estimated Peak Discharge at the Boverton Gauge (8.45km²)

AEP / Return Period	Peak Discharge (m ³ /s)
20% AEP (1 in 5 year)	4.4
5% AEP (1 in 20 year)	6.1
2% AEP (1 in 50 year)	7.3
1% AEP (1 in 100 year)	8.4
1% AEP + Climate change (1 in 100 year plus climate change)	10.1
0.1% AEP (1 in 1000 year)	14.4

These values compare well for the final peak flow estimates presented in the Environment Agency Wales 2001 report, although the 20% AEP event is slightly higher.

Model Hydrology used in HEC-RAS

As the WinFAP FEH method only produces an estimate of peak flows, an ReFH hydrograph was produced for the 1% AEP flood event for the whole (8.45km²) Boverton Brook catchment. The ratios between its peak flow and the various estimates of peak flow for each return period flood event derived previously using WinFap FEH were then obtained. The catchment descriptors as updated previously were used in the ReFH model.

The model has three inflow hydrographs: two normal flow hydrographs for the upper Boverton Brook and the Llanmaes Brook and a uniform inflow hydrograph to represent water entering the Boverton Brook between the upper Boverton hydrograph and the confluence with the Llanmaes Brook. These were derived by running ReFH to produce a 1% AEP flood event hydrograph for each of these 3 sub-catchments. These hydrographs were then scaled by the ratios derived for the overall catchment and entered into HEC-RAS.

In all cases the model outflow matched well with the flood flows estimated previously. However, some minor scaling factors (between 1.02 and 1.10) were applied to the inflow hydrographs so that the expected catchment outflows matched the values in **Table 3.6**.

Key catchment parameters are shown in **Table 3.7**. ReFH output is included in **Appendix D**.

Table 3.7 FEH (version 2) catchment parameters

Parameter	Boverton Brook (upstream inflow)	Boverton Brook (upstream of junction with Llanmaes Brook)	Boverton Brook (At B4265 road bridge)	Llanmaes Brook (at junction with Boverton Brook)
Grid Reference	SS 9960 6925	SS 9870 6885	SS 9840 6865	SS 9865 6885
AREA (km ²)	1.53	2.78	8.45	5.33
URBEXT1990	0.0000	0.0193	0.0199	0.0124
URBCONC1990	0.000	0.37	0.472	0.486
BFI	0.408	0.408	0.408	0.408
Time to Peak (hr)	12.25	12.25	12.25	12.25
Timestep (hr)	0.25	0.25	0.25	0.25
Season (W or S)	Winter	Winter	Winter	Winter

- URBEXT and URBCONC are parameters which describe the degree of urbanisation in a catchment (low = 0, high = 1)
- BFI reflects the importance of baseflow in the catchment (low = 0, high = 1)

With regards to the Boverton and Llanmaes catchments north of the B4265, the degree of urbanisation in the catchment has not changed significantly in recent years. The area of the site (the western portion of West Camp) that drains to the site was developed pre-1960s, whilst the remaining catchment areas are predominantly rural and have seen limited development.

Table 3.8 shows the parameters used in the HEC-RAS model.

Table 3.8 HEC-RAS model parameters

Parameter	Value
HEC-RAS model	Unsteady
Manning's n (in-channel flow)	0.035 to 0.045 – clean channel in places with more overgrown vegetation in other sections
Manning's n (floodplain flow)	0.035 to 0.045 – short grass through to shrubby growth
Normal depth (Friction Slope)	0.01 – parallel to bed slope
Description of Model	
Cross-section	Details
Boverton 27	Channel plus floodplain cross-section (see Plate B.37 to B.41)
Boverton 26	Channel plus floodplain cross-section (see Plate B.36)
Boverton 25.5	Channel plus floodplain cross-section U/S Farm access track
Boverton 25.4	Channel plus floodplain cross-section D/S Farm access track (see Plate B.35)
Boverton 25	Channel plus floodplain cross-section

Boverton 24	Channel plus floodplain cross-section
Boverton 23	Channel plus floodplain cross-section
Boverton 22.1	Channel plus floodplain cross-section U/S small wood bridge
Boverton 22	Channel plus floodplain cross-section D/S small wood bridge
Boverton 21	Channel plus floodplain cross-section (see Plate B.34)
Boverton 20	Channel plus floodplain cross-section
Boverton 19	Channel plus floodplain cross-section
Boverton 18	Channel plus floodplain cross-section (see Plate B.33)
Boverton 17.5	Channel plus floodplain cross-section U/S Llanmaes Road bridge (see Plate B.32)
Boverton 17.4	Channel plus floodplain cross-section D/S Llanmaes Road bridge (see Plate B.30)
Boverton 17	Channel plus floodplain cross-section (see Plate B.29)
Boverton 16	Channel plus floodplain cross-section
Boverton 15	Channel plus floodplain cross-section
Boverton 14	Channel plus floodplain cross-section (see Plate B.28)
Boverton 13	Channel plus floodplain cross-section (see Plate B.26)
Boverton 12	Channel plus floodplain cross-section
Boverton 11	Channel plus floodplain cross-section (see Plate B.25)
Boverton 10.5	Channel plus floodplain cross-section U/S Farm access track
Boverton 10.4	Channel plus floodplain cross-section D/S Farm access track
Boverton 10	Channel plus floodplain cross-section (see Plate B.25)
Boverton 9	Channel plus floodplain cross-section
Boverton 8	Channel plus floodplain cross-section
Boverton 7	Channel plus floodplain cross-section (see Plate B.23)
Boverton 6.5	Channel plus floodplain cross-section U/S Farm access track (see Plate B.23)
Boverton 6.4	Channel plus floodplain cross-section D/S Farm access track (see Plate B.22 & 23)
Boverton 6	Channel plus floodplain cross-section (see Plate B.21 & 22)
Boverton 5.5	Channel plus floodplain cross-section U/S railway culvert (see Plate B.20)
Boverton 5.4	Channel plus floodplain cross-section D/S railway culvert (see Plate B.18)
Boverton 5	Channel plus floodplain cross-section (see Plate B.16 and B.17)
Boverton 4.5	Channel plus floodplain cross-section U/S access track
Boverton 4.4	Channel plus floodplain cross-section D/S access track
Boverton 4	Channel plus floodplain cross-section (see Plate B.15)
Boverton 3.5	Channel plus floodplain cross-section U/S B4265 (see Plate B.14)
Boverton 3.4	Channel plus floodplain cross-section D/S B4265 (see Plate B.12 & B.13)
Boverton 3	Channel plus floodplain cross-section (see Plate B.12)
Boverton 2	Channel plus floodplain cross-section (see Plate B.12)
Llanmaes 8	Channel plus floodplain cross-section
Llanmaes 7	Channel plus floodplain cross-section

Llanmaes 6	Channel plus floodplain cross-section
Llanmaes 5	Channel plus floodplain cross-section U/S Llamaes FAS dam (see Plate B.42 and B.43)
Llanmaes 4.4	Channel plus floodplain cross-section D/S Llamaes FAS dam (see Plate B.44)
Llanmaes 4	Channel plus floodplain cross-section (see Plate B.44)
Llanmaes 3	Channel plus floodplain cross-section (see Plate B.44)
Llanmaes 2	Channel plus floodplain cross-section (see Plate B.25)

The Mannings 'n' value is a parameter used to represent the roughness of channel and floodplain surfaces and vegetation. Rougher values represent more resistance to flow leading to a higher flow stage for a given discharge (values are taken from Chow, 1959).

The Normal Depth (Friction Slope) is used by HEC-RAS in calculating the conveyance (depth and velocity) of water through channel reaches.

The blockage analysis includes for an 85% blockage of the Llanmaes Road bridge culvert, the railway embankment culvert and the Llanmaes FAS.

A sensitivity analysis was carried out on the 1% flood levels by increasing and decreasing the Manning's 'n' number by 10%. Analysis showed that increasing the Mannings 'n' by 10% led to flows increasing in depth by up to 0.07m and decreasing in depth by up to 0.15m. However, analysis showed that decreasing the Mannings 'n' by 10% led to flows increasing in depth by up to 0.39m and decreasing in depth by up to 0.08m. Depths generally increased by 0.30 to 0.39m on the Llanmaes Brook between the Llanmae FAS and the confluence with the Boverton Brook, and on the Boverton between this confluence and the railway culvert. Further sensitivity analysis showed that for the 0.1% AEP event decreasing the Mannings 'n' by 10% led to (with one exception) flows increasing in depth by up to 0.06m and decreasing in depth by up to 0.12m. The exception being immediately downstream of the Llanmae FAS a depth increase of 0.6m was noted. Examination of the model indicated this was a backwater effect associated with the railway culvert's capacity being exceeded and water flowing along the Boverton Road and under the railway bridge before returning to the Boverton Brook. Less difference was noted on the 0.1% AEP flood event compared to the 1% flood event as this bypassing process is already underway during the 0.1% AEP flood event, whereas for the 1% event the increase in roughness causes a large increase in flows. Overall the sensitivity analysis shows that with the proposed 600mm of freeboard development can be safely place outside of TAN15 Flood Zone C.

With regards to the sensitivity of the Normal Depth, reducing this by 10% in the 1% AEP scenario, led to negligible changes in two cross-sections (by plus and minus 0.01m respectively). Again, increasing this by 10% in the 1% AEP scenario, led to negligible changes in two cross-sections (by plus and minus 0.01m respectively). In both cases, both of these cross-sections were downstream of the railway culvert, outside of the area of interest (i.e. downstream of development areas).

Figure 3.6 shows the location of the HEC-RAS model cross-sections, and all of the modelled flood extents. Output levels from the HEC-RAS model are summarised in **Table 3.9**. A site visit was carried out on February 11th 2009 in order to ground truth the flood extents. The 0.1% AEP with blockages flood extent is shown alongside the route of the NAR and the Tremains Farm, North of West Camp and South west of Picketston SFA sites in **Figure 3.7**. **Figure 3.7** also shows the section of the Boverton Brook for which diversion proposals are to be prepared.

Due to the topography of the Boverton Brook and Llanmaes Brook valleys, the flood extents on **Figure 3.6** are relatively consistent and tend to increase in depth with a limited increase in the flood extent area as the flood extents become more extreme. The existing Llanmaes Lane road bridge and railway embankment act as key restrictions to flow, causing water to back up. The railway embankment in particular causes flows to pass along the Boverton Road underneath the railway before rejoining the Boverton Brook south of the railway embankment. The impact of the flood storage upstream of the Llanmaes FAS can be seen. **Figure 3.7** shows that the SFA housing can be accommodated in the proposed sites in areas of Flood Zone A (Flood Zone C is the 0.1% AEP flood extent shown on this figure). With regards to the NAR it can be seen that at Picketston the footprint of the proposed route overlaps with the 0.1% AEP floodplain. As part of the scheme for diversion of the upper Boverton Brook ditches (indicated in blue on **Figure 3.7**) it will be necessary to provide replacement flood storage in substitute for the floodplain encroached on by this section of the NAR.

Table 3.9 Predicted Water Surface Levels

Cross Section number	Chainage	WSL 20% AEP	WSL 5% AEP	WSL 2% AEP	WSL 1% AEP	WSL 1% AEP + climate change	WSL 0.1% AEP - No Blockage	WSL 0.1% - 85% Blockage
Boverton Brook (Chainage starts from GR: SS 995 694, within the Picketston site)								
27	96.3	41.88	41.98	42.01	42.05	42.12	42.22	42.22
26	42.0	41.74	41.79	41.8	41.82	41.85	41.89	41.89
25	15.0	41.34	41.44	41.48	41.51	41.55	41.63	41.63
24	34.0	41.22	41.30	41.33	41.36	41.41	41.46	41.46
23	105.7	40.92	41.01	41.04	41.07	41.10	41.16	41.16
22	124.0	39.31	39.43	39.47	39.51	39.57	39.68	39.68
21	79.3	38.80	38.91	38.94	38.98	39.03	39.10	39.11
20	14.8	38.64	38.80	38.81	38.83	38.85	38.89	38.93
19	17.0	38.64	38.80	38.81	38.83	38.85	38.89	38.93
18	9.8	38.64	38.79	38.81	38.83	38.85	38.88	38.93
17	39.6	37.93	37.99	37.99	38.02	37.99	37.99	37.99
16	66.8	37.47	37.52	37.52	37.52	37.51	37.56	37.56
15	65.0	36.64	36.75	36.79	36.89	36.92	36.96	36.96
14	122.7	36.03	36.11	36.17	36.25	36.30	36.34	36.40
13	65.7	35.35	35.45	35.54	35.69	36.04	36.16	36.32
12	57.0	35.33	35.44	35.53	35.69	36.04	36.16	36.32
11	13.2	35.33	35.44	35.53	35.69	36.04	36.16	36.32
10	8.5	35.33	35.44	35.53	35.68	36.04	36.16	36.32
9	25.5	35.33	35.44	35.53	35.68	36.04	36.16	36.32

Cross Section number	Chain-age	WSL 20% AEP	WSL 5% AEP	WSL 2% AEP	WSL 1% AEP	WSL 1% AEP + climate change	WSL 0.1% AEP - No Blockage	WSL 0.1% - 85% Blockage
8	60.0	35.33	35.44	35.53	35.68	36.04	36.16	36.32
7	6.0	35.32	35.43	35.52	35.68	36.03	36.15	36.32
6	19.5	35.01	35.31	35.48	35.66	35.79	36.06	36.31
5	26.0	33.64	34.13	34.58	35.02	35.13	35.15	35.15
4	18.4	33.54	34.12	34.57	35.01	35.12	35.15	35.15
3	21.0	33.07	33.23	33.32	33.40	33.51	33.74	33.74
2	25.4	32.92	33.07	33.14	33.21	33.30	33.50	33.49
Llanmaes Brook (Chainage starts from GR: SS 985 691, on Llanmaes Brook U/S of proposed NAR)								
8	80.2	39.27	39.89	39.98	39.99	40.05	40.13	40.23
7	41.5	38.70	39.89	39.96	39.99	40.04	40.12	40.23
6	41.5	38.71	39.89	39.96	39.98	40.04	40.12	40.23
5	41.0	38.71	39.89	39.96	39.98	40.04	40.11	40.22
4	73.2	36.18	36.32	36.40	36.44	36.51	36.67	36.66
3	56.8	35.36	35.48	35.56	35.70	36.04	36.15	36.32
2	75.0	35.33	35.44	35.53	35.68	36.04	36.16	36.32

WSL = Water Surface Level

All levels in m AOD

These flood extents have been used to set out the aspects of the development adjacent to the Boverton and Llanmaes Brooks (the Tremains Farm Picketston South West and North of West Camp SFA areas, as well as the design of the NAR). Buildings will be located within the Flood Zone A portion of the SFA sites, with areas located in Flood Zone C set aside as open space. This is discussed further in **Section 4**.

With regards to the diversion of the upper ditches of the Boverton Brook, discussions with the Environment Agency (26th February 2009) indicated that this is potentially feasible in outline. However, agreement would need to be reached over the detail of the proposals. These would need to ensure there is no increase in flood risk, and like-for-like replacement is provided. Wholesale culverting of the watercourse under the sports pitches will not be acceptable. For NAR road access points which will cross this ditch-course part of the upper Boverton Brook, the culverts should be designed to take the 1% AEP flow with climate change allowance.

It is not proposed to set built development immediately adjacent to this watercourse, with developments being set back from the edge of the 0.1% AEP + blockage flood extent. Where the upper ditches will remain, a clear 4m wide access strip adjacent to both sides will be provided for maintenance access.

3.3.2 Nant y Stepsau

This watercourse issues approximately 750m upstream/east (GR: SS 9961 6916) of the Picketston House road bridge over the Nant y Stepsau (GR: ST 0032 6937). For most of this distance the watercourse is a poorly defined ditch, running roughly parallel to the Boverton to Eglwys Brewis road, whilst just upstream of the road bridge the watercourse passes through a wider boggy area. Within this reach flow is barely perceptible; however downstream of the road bridge where it becomes an Environment Agency Wales Main River², the watercourse is more open in nature, with in-channel vegetation and notable flow.

This upper ditch-course has not been modelled as the existing ditch is poorly defined and it is planned to improve the watercourse during the development. However, a basic hydraulic analysis has been carried out based on catchment areas.

- Nant y Stepsau (ST 003 693 - Picketston House road bridge, start of the Main River section). Catchment area is 1.44km² and using catchment descriptors for FEH v2, with the BFI updated to 0.408 (based on Boverton Brook) in ReFH, the 1% AEP plus climate change flood peak is 3.4 m³/s and the 0.1% AEP flood peak is 4.9m³/s; and

Improvements to the NAR corridor consist of works to the existing road corridor, and the forming of new junctions. Discussions with the Environment Agency (26th February 2009) indicated that any pipe crossings required where this ditch-course passes under road access ways should be designed to take the 1% AEP flow with climate change allowance.

It is not proposed to set built development immediately adjacent to this watercourse; the nearest development (car park and southern edge of the running track) will be set back. A clear access strip for maintenance access will be provided adjacent to both sides of the proposed chain of swales (see 'DTC proposed drainage strategy' figure in **Appendix C**) and attenuation basins that will replace the upper Nant y Stepsau ditch.

3.4 Other Sources of Flood Risk

3.4.1 Flooding from Surface Water Run-On and Run-Off

Surface water run-off

Extreme rainfall and saturated soil conditions could potentially produce shallow overland flow, causing surface water flooding at various locations across the site. Depending on location, these would initially collect and pond in any relatively depressed areas of the site before flowing towards the various watercourses surrounding the site. Anecdotal accounts and analysis of rainfall events indicates that the land surrounding the St Athan site is relatively prone to producing surface water runoff. However under extreme events where rainfall intensity exceeds the infiltration capacity of the soil/geology, as at any location, surface water runoff will occur.

The proposed SuDS and site design informed by the SWDSs will ensure that surface water is managed up to the 1% AEP rainfall event (as per CIRIA report C697). Given the rural setting of the overall site and the fact that there are no receptors (property) between the site perimeter and downslope watercourses, immediate impacts due to runoff from the site during an extreme

² Main River means that the Environment Agency have a flood defence responsibility along the watercourse (other watercourses will be classified as Ordinary watercourses).

rainfall event (in excess of the 1% AEP event) are likely to be limited. For rainfall events of these extreme intensities, the runoff volumes are unlikely to be influenced by the development, as rainfall will be of such an intensity that infiltration will be exceeded regardless of the surface type (greenfield/impermeable hardstanding etc). Separate recommendations are made within this FCA for managing the sites surface water runoff, which are to be developed within the individual SWDSs.

Consultation with the Vale of Glamorgan (meeting 27/03/2009) has indicated several localised areas with surface water runoff issues: Llammaes village (although here surface water runoff is associated with problems along an Ordinary Watercourse); St Athan (between Llantwit Road and Glebeland Place); and just north of St Athan at Pantynawel (from the steep slope immediately to the north).

The Llanmaes and St Athan (between Llantwit Road and Glebeland Place) are associated with runoff from areas located outside the influence of the St Athan redevelopment (i.e. the runoff occurs from higher land separated from the site by watercourses). A land drainage scheme has been put in place by the VoG for the surface water runoff issue at St Athan (between Llantwit Road and Glebeland Place). The Castleton Field Training Area (FTA) is set on land above the Pantynawel area, however the FTA area does not slope towards Pantynawel, and in addition the use of this area as a FTA will not change its rural character and so is not expected to exacerbate runoff issues.

Surface water run-on

The main area of the site (West Camp/RDH/Batslays/East Camp), the Eglwys Brewis/Castleton and the Tremains Farm SFA areas have limited risk of surface water run-on due to their location on plateaus surrounded by the valleys of the local watercourses. The Picketston sports & ETA site as well as the Picketston South West and North of West Camp SFA sites have more of a risk, due to the larger upslope areas to the north. It has been noted that historic flooding of the Boverton to Eglwys Brewis road occurs for short periods after heavy rainfall, primarily associated with the lack of drainage to the road and the restricted capacity of the existing silted Nant y Stepsau ditch-course. However, it is considered that this risk can be managed through appropriate site layout and design.

Suggested mitigation is by design, such that where possible long terraces of contour-parallel buildings are avoided and building thresholds are raised slightly above local ground levels (with minor ramps where necessary), so as to design out the risks of surface water flow paths being either blocked by buildings and collecting and/or entering buildings.

3.4.2 Flooding from Groundwater

Parsons-Brinkerhoff, (2004) found water levels in the Lower Jurassic Porthkerry Formation (interbedded limestones and mudstones) beneath the site were to be typically 0.3m to 3m below the ground surface, with a seasonal variation of up to 4m. It is understood that the Porthkerry Formation extends to approximately 85m below ground level, being underlain by the Carboniferous Limestone Formation. The aquifer has been classified by the Environment Agency's Groundwater Vulnerability mapping as a minor aquifer, with soils classified as having a high leaching potential due to their freely draining nature. Minor Aquifers are formations with low secondary permeability generally along fractures or fissures. Groundwater yield is generally not significant enough for public abstraction, but is important for local supplies and in supplying base flow to rivers. The Lower Jurassic Porthkerry Formation is a multi-layered aquifer with interbedded limestones and mudstones. The limestone bands form discrete

individual water-bearing horizons, separated by less permeable layers, which leads to distinctive separate aquifers in a given profile and also to perched groundwater levels.

The Environment Agency Wales has supplied levels for the Llantwit Borehole #1 and #2, both of which are located adjacent to the Llanmaes Brook, west of the site. Llantwit Major #1 borehole monitors groundwater levels in a lower lying Carboniferous Limestone aquifer, whilst Llantwit Major #2 borehole monitors groundwater in the near-surface Porthkerry Formation limestone aquifer. Levels in the Llantwit Major #2 borehole are therefore the most relevant to flood risk from groundwater to the site. Details are presented in **Table 3.10**.

Table 3.10 Environment Agency Wales – Llantwit Borehole Water Levels

Borehole	Llantwit #1	Llantwit #2
Grid Reference	SS 9719 6971	SS 9720 6970
Datum (ground surface level)	56.83m AOD	56.72m AOD
Water Level (min 2002 to 2008)	8.57m AOD	52.36m AOD
Water Level (max 2002 to 2008)	32.56m AOD	55.77m AOD
Water Level (mean 2002 to 2008)	19.19m AOD	54.56m AOD

It is therefore understood that in general groundwater levels are close to the surface in many places.

However, the risk of groundwater flooding can be managed by appropriate masterplanning of the development, by situating development away from areas of known spring activity, and away from the valley bottoms and lower valley sides. The setting of development outside of the extent of the 0.1% AEP fluvial flood event outline will help to provide this mitigation, since it is these low lying areas that are most likely to be impacted by high groundwater levels. Appropriate foundation and basement construction techniques can be deployed to manage any residual risks.

3.4.3 Flooding from Sewers

The sites foul water will be piped to either the Aberthaw WwTW (by gravity) or the Llantwit Major WwTW (by pumped rising main). The majority flows will be directed to the enlarged Llantwit Major WwTW. There is a residual risk of foul water flooding should this pumping system fail, or a blockage occurred in either of the trunk sewers. Additionally there is a residual risk of minor local blockages/overloading.

The sewerage system will be designed to cope with varying flows of sewerage. The risk of sewer flooding can be considered as a residual risk, since if any flooding did occur it would be a localised event.

3.4.4 Flooding from Canals, Reservoirs and Other Artificial Sources

There are no canals, reservoirs or other artificial water bodies within close proximity of the site.

3.4.5 Existing Flood Defence Structures

With the exception of the Llanmaes Flood Alleviation Scheme (FAS), there are no existing flood defence structures within close proximity of the site.

The Llanmaes FAS consists of a small earth embankment across the Llanmaes Brook, located at GR SS 9857 6896, below Llanmaes village, but above the Llanmaes confluence with the Boverton Brook. Flows passing through the embankment are restricted by the orifice size of the pipe through the embankment. This provides a degree of attenuation to flows coming down the Llanmaes Brook, helping to reduce peak flows downstream.

In Boverton, the stone walls forming the banks of the Hoddnant (which the Boverton and Llanmaes Brooks feed into) have been raised and sealed, due to a localised area of flood risk at The Causeway bridge in Boverton village square. Based on historical flooding the Environment Agency has indicated that in Boverton there are 6 properties known to be at risk along the Boverton Brook. However the exact number of properties potentially at risk of flooding under the 0.1% flood is not known. Environment Agency pre-feasibility studies indicate that potential schemes to alleviate flooding would be uneconomic, as the costs of various alleviation options are high in comparison to the relatively small number of properties at risk.

The Environment Agency's 2001 report details how the limited capacity ($4.5\text{m}^3/\text{s}$) of the culvert under The Causeway road is the key issue at this location. Modelling of the Boverton Brook upstream indicates that the restrictive culvert under the railway line acts to throttle the flow passing down the Boverton/Hoddnant to the centre of Boverton. The backing up of this culvert causes floodwaters to be stored on the low lying land at Tremains Farm.

Within the site there are several existing attenuation facilities, principally the two large swales adjacent to the Red Dragon Hangar (RDH). These features store rainfall during a storm event, allowing it to both infiltrate directly into the bedrock, and to outflow at a restricted rate to the Nant y Stepsau. The functioning of these will not be impeded by the development proposals.

3.5 Climate Change

As confirmed with the Environment Agency Wales, as the 0.1% AEP flood flow is already an extreme event, a climate change allowance has not been incorporated. In support of the investigation of the 0.1% AEP flood extent, the 20%, 5%, 2% 1% AEP and 1% AEP plus climate change flood extents have been estimated and their extents mapped. Allowance has though been made for an 85% blockage of key culverts along the Boverton and Llanmaes Brooks.

This has been further supplemented with the inclusion of a 600mm freeboard above the 0.1% flood level when masterplanning development areas proximal to watercourses.

Taken together, it is considered that the extreme flood event modelled (with blockages included) and the 600mm freeboard provide a large degree of resilience against the impacts of climate change on flood levels and extents.

4. Surface Water Management

As required by TAN15, an appropriately designed Sustainable Drainage System (SuDS) will be required for the development. This will ensure that site runoff rates are not increased above existing rates by the development, and that flood risk is not increased to people and property downstream of the development. Permitted discharge rates have been agreed with the Environment Agency for the site.

4.1.1 Pre-design discussions

The requirements for surface water management at the MoD St Athan site were discussed with the Environment Agency during a meeting held on the 23rd July 2008. The following criteria were agreed:

- Nant y Stepsau and Rhyl Stream catchments – permitted greenfield runoff rate of 7.4 l/s/ha;
- Boverton Brook catchment (includes Llanmaes) – permitted greenfield runoff rate of 3.9 l/s/ha;
- Climate change allowances:
 - Allowance for a 20% increase in rainfall intensity in the drainage modelling, except SFA areas, where due to the 100 year design life a 30% increase in rainfall intensity should be included for in the drainage modelling;
 - Fluvial climate change allowance of +20% on 1% AEP flood event flows to be used for sizing of smaller culverts over ditches at site access points;
- Design lifetime of buildings – 50 years (SFA 100 years);
- Surface water Drainage design criteria:
 - Pipe sizing to the 3.33% event; and
 - Attenuation features to the 1% AEP event with an additional 20% capacity allowance for increases in rainfall intensity due to climate change (30% for SFA areas).
- The SuDS options utilised on site will need to avoid providing permanent open-water near the runways in order to minimise likelihood of bird strikes. Therefore for areas near the runway, underground tanks and pipes are currently favoured. Elsewhere, generally dry features will be favoured. It is therefore currently proposed to utilise swales, drainage blankets and over-wide ditches (swales), with some void storage in tanks, pipe tanks and void storage beneath areas of hard standing in areas nearer the runway;
- Justification will be needed if at any location SuDS are not to be provided.
- The developers will need to provide details of the long term maintenance arrangements for the proposed SuDS, covering responsibilities for their future maintenance. This is in

order to ensure that they are maintained properly, and that if any problems occur arrangements can be put in place for these to be remedied.

4.1.2 Current Site Drainage

At present, apart from the recently constructed RDH (which has a drainage system designed to attenuate surface water runoff to a greenfield rate of 7.4 l/s/ha), surface water runoff enters these watercourses unattenuated, and to soakaways principally located in the Batslays area of the site. However, some defacto attenuation of drainage is provided since the overall drainage rate is limited by pipe sizing.

The Environment Agency Wales have requested that for areas of existing development that are to be redeveloped, runoff rates should not be increased above existing rates, and ideally should be reduced by 20% below existing rates, in order to contribute to reducing flood risk elsewhere in the catchment. In order to achieve this, the design of the redeveloped sites drainage carried out for all components of the site has been based on discharge to watercourses at the greenfield runoff rates. This will mean that runoff will be attenuated back to the natural runoff rate, providing a betterment against the existing systems, which (with the exception of the RDH) drain directly to adjacent watercourses with limited attenuation of flows.

Figure 4.1 shows the current layout of the site drainage system, attenuation basins, and discharge points.

4.1.3 Future Site Drainage

The St Athan Surface Water Drainage Strategy Drainage report contains details of the proposed infrastructure for each development area. This includes an outline of key components of the proposed future layout of the site drainage system, including routes of the main surface water drainage pipes, attenuation basins, and discharge points.

In terms of new drainage infrastructure, the following discharge points are proposed:

- Boverton Brook:
 - B4265 and NAR junction (GR: SS 985 686);
 - Tremains Farm (GR: SS 985 687);
 - North of West Camp & Picketston SFAs (GR: SS 992 691);
 - NAR (GR: SS 995 692); and
 - Part of Picketston DTC (GR: SS 995 692).
- Nant y Stepsau (all at GR: ST 003 693):
 - Part of Picketston DTC;
 - ABP North; and
 - NAR (improved stretch of existing road).
- Rhyl Stream:
 - East Camp DTC and ABP South - re-use of existing discharge point, located at GR: ST 011 683.

Detailed plans of the individual outline drainage designs for the components of the redevelopment (DTC, ABP sites, SFA sites and the NAR) are located in **Appendices B to D**.

The drainage systems for all parts of the site will be designed according to the Environment Agency Wales requirements. Piped systems will have capacity for up to the 3.33% annual probability flow, and for flows between the 3.33% and 1% annual probability, these will be routed towards the proposed SuDS features and attenuated. All systems will be designed with a 20% (30% for SFA areas) allowance for the impacts of climate change on rainfall intensity.

The detailed guidance available in CIRIA C697 “The SuDS Manual”, C698 “Site Handbook for the Construction of SuDS” and Sewers for Adoption (6th Edn.) will be followed as the finalised drainage strategies are developed.

This FCA and the drainage assessments that it references are designed to show that it is feasible to manage surface water from the development appropriately. Where designs are currently sufficiently advanced, this has been undertaken by producing outline assessments of each development area, and sizing of the components of the sustainable drainage system – i.e. the attenuation features. Detailed SuDS arrangements will need to be finalised during the detailed drainage design stage.

The outline proposals for each area of the redevelopment are currently:

DTC – Defence Technical College

The outline drainage strategy for the East Camp area of the DTC, the Red Dragon Hangar site and Picketston is included in **Appendix C** (see ‘DTC Proposed Drainage Strategy’ figure). Drainage from the East Camp DTC area will follow the existing drainage routes via attenuation to the Rhyl Stream, using new pipes to replace parts of the existing piped system, directing surface water flow to a strategic (providing attenuation for the whole East Camp DTC area) underground attenuation tank on the southern side of East Camp. The piped system serving the RDH site will be used as far as possible for the new RDH drainage and adjacent buildings, which is limited by a penstock control structure prior to discharging to the Nant y Stepsau across Eglwys Brewis Road. The two attenuation ponds located at the northern side of this site will continue to be used during storm events to attenuate flow peaks. However, based on final impermeable areas some localised attenuation basins, or an enlargement to the existing basin located to the west of the RDH will be required. SuDS options for the Picketston component of the DTC site are still being investigated, however the greater distance away from the runway, and lighter traffic mean that there is more scope for open attenuation basins and porous paving. Runoff from the Picketston DTC will be split between the Boverton and Nant y Stepsau watercourses (**Figure 4.2**). It is likely that a combination of features such as attenuation basins, swales, rainwater harvesting, permeable car parks, soakaways and tank systems will be considered. Overall, runoff will be attenuated to the greenfield runoff rate of 3.9 l/s/ha where it flows to the Boverton Brook and of 7.4 l/s/ha where it flows to the Rhyl Stream and Nant y Stepsau, in both cases with attenuation to the 1% AEP rainfall event plus climate change allowance.

ABP sites and NAR – Aerospace Business Parks and Northern Access Road

ABP South (south of the main runway) and SAR

Runoff from the hangar roofs and concrete aprons will be collected and stored underground in a pipe storage system. This will be routed, alongside runoff from the SAR eastwards towards the Rhyl Stream in St John’s valley and a secondary runoff storage tank. Overall flows will be

attenuated to the greenfield runoff rate of 7.4 l/s/ha with attenuation to the 1% AEP rainfall event plus climate change allowance. Some roof runoff will be set aside for re-use via rainwater harvesting. Rainwater harvesting will be via a separate system to the SuDS, and these relatively small volumes have not been included in the SuDS attenuation calculations. The drainage from the realigned section of the B4265 will be routed to the existing drainage point for this section of the B4265. The discharge from this section will be maintained at existing rates.

ABP North (North of the main runway/west of the former secondary runway)

Runoff from the hangar roofs and concrete aprons will be collected and stored underground in a pipe storage system. More lightly trafficked areas of hardstanding (associated car park areas) will be constructed on open stone tanks to provide further attenuation. Runoff will be routed alongside the secondary runway and alongside the ABP north access road towards the outfall to the Nant y Stepsau adjacent to the Boverton-Eglwys Brewis road. Some roof runoff will be set aside for re-use via rainwater harvesting. Rainwater harvesting will be via a separate system to the SuDS, and these relatively small volumes have not been included in the SuDS attenuation calculations. Overall flows will be attenuated to the greenfield runoff rate of 7.4 l/s/ha with attenuation to the 1% AEP rainfall event plus climate change allowance.

NAR (west of the Llanmaes Brook road bridge) and junction with B4265

Runoff will be collected by kerb-side drains and swales and routed southwards to an outlet adjacent to the B4265 crossing of the Boverton Brook. Overall flows will be attenuated by a SuDS feature to the greenfield runoff rate of 3.9 l/s/ha with attenuation to the 1% AEP rainfall event plus climate change allowance

NAR (east of the Llanmaes Brook road bridge – to Picketston)

Runoff will be discharged to the Boverton Brook at an outlet adjacent to the Carpenters Arms Pub. For the portion of road southwest of this, runoff will be collected by kerb-side drains and swales and routed northeast-wards alongside the road to the outfall, with storage provided by longitudinal storage tanks. For the section between this pub and the new junction with the existing Boverton to Eglwys Brewis Road, flows will be routed westwards to this outfall. An attenuation feature will be located at this point. Overall flows will be attenuated by a SuDS feature to the greenfield runoff rate of 3.9 l/s/ha with attenuation to the 1% AEP rainfall event plus climate change allowance.

NAR (Picketston to Eglwys Brewis)

This section of the NAR represents the improved existing Boverton to Eglwys Brewis road. Drainage will be routed eastwards alongside this road to an attenuation feature located adjacent to the Picketston House road bridge across the Nant y Stepsau. Overall flows will be by a SuDS feature attenuated to the greenfield runoff rate of 7.4 l/s/ha with attenuation to the 1% AEP rainfall event plus climate change allowance.

SFA sites – Service Families Accommodation

Surface water runoff from the proposed housing to serve the new development will also be treated using SuDS. An outline strategy has been prepared on behalf of the MoD regarding the housing sites. It is proposed that a 'hard' SUDS solution will be implemented, including an aqua-cell geocellular below ground storage and a proprietary Garastor system for residential properties. Prior to discharging into receiving watercourses, suitable pollution screening devices will be installed, for example proprietary by-pass interceptors. Overall runoff will be

attenuated to 3.9 l/s/ha where it flows to the Boverton Brook (Tremains Farm, Picketston South west and North of West Camp) and 7.4 l/s/ha where it flows to the River Thaw (Castleton), in all cases with attenuation to the 1% AEP rainfall event plus climate change allowance.

Off-site road improvements

At the Waycock Road junction it is proposed to construct a new roundabout north of the existing junction, with corresponding sections of road to link it in. Surface water from the new junction will be routed to an attenuation features located in the centre of the roundabout. Surface water from retained areas of existing hardstanding will continue to discharge at existing rates. Water will be attenuated to the 1% AEP event with a 20% allowance for climate change. Discharge from this system is to be routed to River Waycock, located to the north (which via the Kenson River joins the River Thaw at Aberthaw).

Gileston/Old Mill – discharge direct to the River Thaw estuary. Discharge from the new 0.71 ha of road hardstanding will be directed via linear drains, without attenuation.

St Athan road junction – minor works, only limited additional hardstanding and installation of traffic signals. Existing drainage system will be utilised and retained.

4.1.4 Catchment Changes

As a consequence of the development at the site, changes will occur to the existing drainage layout, effectively causing a net transfer of 34.5ha of catchment (and its discharge) to the Nant y Stepsau, from the upper Boverton Brook catchment. The site of the ABP North which currently drains to the Boverton Brook, will return to its natural topographical catchment – i.e. the Nant y Stepsau. The northwest area of the Picketston DTC site which currently drains to the upper Boverton Brook, will be developed as the ETA, drainage here will be intercepted and attenuated, draining to the Nant y Stepsau. The south west corner of the Picketston DTC site which currently drains to a shallow ditch, (the upper Nant y Stepsau) will drain to the upper Boverton Brook. **Figure 4.2** shows these changes. However, these discharges will all be attenuated to greenfield rates (7.4l/s/ha) this will only increase flows by 0.26m³/s. This will mean that flood peaks and the potential for scour are not increased. This net transfer will provide a small but important contribution to reducing flood risk in the Boverton Brook catchment.

4.1.5 Future Maintenance

It has been recognised that the exact ownership of assets needs to be agreed before the process of adoption and consenting, and planning application submission. The adopting organisations will be:

- SFA sites and DTC sites – to be maintained by MoD contractor (currently under project Aquatrine, this is Brey);
- ABP north and south – will be vested in a management organisation; and
- Road improvements – to be adopted by the Vale of Glamorgan.

4.1.6 Foul flows

All extra foul water generated by the redevelopment of St Athans will be routed to the Llantwit Major STW. Works are required to provide adequate capacity to treat extra flows, including an

additional settling tank. The amount of foul water routed from the site to the Aberthaw STW will not be increased.

4.2 Climate Change Allowances

As the 0.1% AEP flood event (which defines the extent of TAN15 Flood Zone C) is already an extreme event, it has been confirmed by the Environment Agency Wales that a climate change allowance should not be incorporated into this scenario. However, in support of this flood extent, a variety of flood scenarios (20%, 5%, 2%, 1% and 1% + climate change allowance events, as well as the 0.1% AEP event) have been modelled and are presented in **Section 3**. The hydrology of the Boverton catchment has been investigated in detail using historical catchment data, and information from other hydrologically similar catchments in order to gain an understanding of flood magnitudes. Allowance has though been made for an 85% blockage of key culverts along the Boverton and Llanmaes Brooks.

In terms of surface water management, a 20% increase in rainfall intensity (30% increase for SFA areas) has been allowed for when producing the Surface Water Drainage Strategy. The differences being due to the differing design lives (100 years for residential, 50 years for other aspects of the development).

This has been further supplemented with the inclusion of a 600mm freeboard above the 0.1% flood level when masterplanning development areas proximal to watercourses.

Taken together, it is considered that the extreme flood event modelled (with blockages included) and the 600mm freeboard provide a large degree of resilience against the impacts of climate change on flood levels and extents.

5. Proposed Mitigation

5.1 Proposed Mitigation

It is not proposed to place any buildings within areas of Flood Zone C. Since **Section 2** has identified that flood Zone C extends partially within parts of the overall Tremains Farm and North of West Camp SFA areas; **Section 3** has therefore identified the exact extent of Flood Zone C. Areas at risk of flooding will be utilised as open space, with buildings being placed in Flood Zone A (although some necessary appropriately designed road/footpath crossings will need to cross Flood Zone C). The 0.1% AEP flood levels presented in this report, and for subsequent investigations of flood risk (i.e. investigations in support of the proposed diversion of the upper Boverton Brook ditch) should be used to assist in the setting of finished floor levels. A freeboard is also to be added to the modelled flood levels in setting out the developments to provide an additional margin of protection to buildings located at the edge of Flood Zone A. The modelled flood outlines have also been used to ensure the route of the new NAR is placed in Flood Zone A.

With regards to the Picketston DTC and Picketston South West SFA areas, there is a small residual flood risk associated with the small ditch-courses passing through these areas. The Picketston DTC's southern boundary follows the upper ditch-course of the Nant y Stepsau. However, given the small catchment here (less than 1.5km²) flood risk is limited to a thin strip along the ditch. Proposals have been developed to improve this watercourse as part of the SWDS for the redevelopment of the Picketston area for the DTC. It is proposed to divert the upper ditch-course of the Boverton Brook as part of the development in this area. A scheme is to be developed and agreed with the Environment Agency Wales. This scheme will also have to provide compensation for the encroachment of the NAR at Picketston on part of the Boverton Brook's floodplain. The NAR needs to pass through this area in order to tie in with the existing Boverton to Eglwys Brewis Road. The scheme will ensure that the development does not cause any increase in flood risk downstream by allowing for appropriate attenuation of floodwater.

The ABP (north and south), the SAR, RDH, DTC East Camp, ETA, FTA and the Castleton SFA sites are all located solely in Flood Zone A, at minimal risk of flooding.

Where the NAR crosses the Llanmaes Brook, the bridge abutments are to be located outside of Flood Zone C, with a high, clear-span bridge forming the road deck set 600mm above the 0.1% AEP flood extent. A 600mm freeboard will be applied to finished floor levels of buildings in the proposed adjacent Tremains Farm and North of West Camp SFA areas. Along the upper ditch-courses it is also recommended that a 600mm freeboard is applied to buildings in the Picketston South West and Picketston DTC areas which are located along the upper Boverton Brook and Nant y Stepsau respectively. With these measures in place there will be no loss of floodplain storage, or blockage to flood flows.

It is proposed to mitigate the potential increase in runoff from the redevelopment of St Athan by the use of Sustainable Drainage Systems (SuDS). The types of SuDS proposed are dictated by two key factors:

- 1) Site operations: areas adjacent are not suitable for the use of open air features which could attract birds and increase the risk of bird strike. Additionally, some of the ABP

areas adjacent to the runways will be subject to trafficking by heavy vehicles and planes, which will prohibit the use of porous paving.

- 2) Geological characteristics - hard-rock will limit excavation depths, and the infiltration rates will be determined by the characteristics of the local sites geology (degree of fracturing and mudstone/limestone interbedding). The final SuDS scheme will be designed appropriately with reference to this constraint.

For this reason, a wide selection of SuDS have been proposed, with pipe and tank storage adjacent to the runway and in the ABP areas, porous paving in low-traffic areas of the ABP, storage tanks on the southern edge of the east camp component of the DTC, and attenuation basins in the ETA and sports area of the DTC at Picketston, and various SuDS features within the SFA areas. Along the new NAR, linear features consisting of swales and kerb drainage above longitudinal storage will be utilised. Additional attenuation features will be provided adjacent to discharge points, where required to ensure runoff is attenuated to the respective greenfield runoff rate.

The amount of catchment draining to the Rhyl Stream will not be altered by the development. There will be a net diversion of 34.5ha of catchment from the Boverton Brook catchment to the Nant y Stepsau catchment. As this will be attenuated to a greenfield runoff rate of 7.4l/s/ha this will only increase flows by 0.26m³/s.

The following easements have been requested along watercourses in the vicinity of the development (see **Figure 3.3** for Main River locations):

- Main Rivers (Environment Agency Wales) – 7m either side, extending away from banktop
- Ordinary Watercourses (Vale of Glamorgan) – 4m either side, extending away from banktop

These easement strips are required to ensure that development does not encroach on the watercourse corridors preventing maintenance access, and potentially the construction of structures that may obstruct flood flows. The Environment Agency Wales requires that any development proposed within the watercourse corridor (watercourse width plus 7m either side of bank tops) are submitted for Flood Defence Consent (previously Land Drainage Consent). The Vale of Glamorgan has similar requirements for Ordinary Watercourses.

With regards to the re-routing of the upper ditches of the Boverton Brook it is proposed to construct a new stretch of watercourse through the ETA/sports area of the DTC. Before development in this area commences, a detailed scheme for this diversion, developed so as not to increase flood risk will need to be developed and submitted to the Environment Agency Wales for agreement. Like-for-like replacement will occur to ensure there is no habitat loss. If required, an attenuation feature will be created as part of the diversion to ensure that flows downstream are not increased (leading to an increase in flood risk). The most feasible location for this would be the low lying area between the old Boverton to Eglwys Brewis road and the new NAR immediately west of the new junction between these two roads.

Overall the following items will ensure that there is either no impact on flood risk, or a reduction in flood risk:

- setting of development outside of TAN15 Flood Zone C (will prevent development increasing flood risk by reducing flood storage or conveyance);

- the redesign of all of the redeveloped areas drainage to modern standards by provision of attenuation to greenfield rates up to the 1% AEP event with a 20% (30% for the SFA sites) allowance for increases in rainfall intensity due to climate change. Altogether this will provide a betterment compared to the existing unattenuated site runoff;
- new development areas drainage (will ensure that flood risk is not increased by new development); and
- diversion of a 34.5ha of the upper Boverton Brook catchment will provide a small betterment to reduce flood risk downstream in the Boverton Brook catchment. This will occur due to the reduction in catchment area, and hence a small reduction in the size of future flood peaks.

6. Conclusions

6.1.1 Flood Risk

A Flood Consequence Assessment (FCA) has been carried out following the guidance and requirements set out in TAN15. Climate change has been included in the assessment, with the 1% plus climate change flows being modelled and mapped. However as confirmed with the Environment Agency Wales, climate change has not been added to the 0.1% event that defines Flood Zone C, given that it is already an extreme event. In addition allowances for an increase in rainfall intensity due to climate change have been included for in the SWDS, these allowances are 30% for the SFA areas and 20% for all other aspects of the development. The differences in allowance being associated with the longer design life of residential development, compared to non-residential development. The main flood risk to the site is from the watercourses which pass along the boundaries of the main St Athan site. However, there are additional risks associated with high-groundwater levels in the interbedded limestone-mudstone aquifer beneath the site, and associated with surface water run-on onto the site. It is considered that these though can be managed through appropriate site design, at the development layout stage and informed by site investigations.

With regards to fluvial flood risk, the main watercourses of interest are the Boverton and Llanmaes Brooks since development is set further back from the Nant y Stepsau and the Rhyl Stream. A HEC-RAS hydraulic model has been constructed of the Boverton Brook and Llanmaes Brook in order to ensure that the NAR and buildings in the Tremains Farm and South West of Picketston SFA sites can be placed outside of areas Flood Zone C (high risk of flooding) and on land within Flood Zone A (lowest risk). The flood modelling will be used to set out development so that areas of these two sites in Flood Zone C are used for open space. The modelling undertaken has also included for blockages to the key culverts underneath the Llanmaes Road at Old Froglands, the railway embankment and under the B4265. **Figures 3.6 and 3.7** show the outputs of the flood modelling. Overall the hydraulic modelling follows a precautionary approach, to ensure that new development is not placed in areas at high risk of flooding. A 600mm freeboard is to be applied to finished floor levels in adjacent SFA areas to ensure that finished flood levels here are above this flood level.

Proposed mitigations are outlined in full in **Section 5**. In summary:

1. **DTC East Camp, RDH and Energy Centre** – TAN15 Flood Zone A;
2. **DTC Picketston** (including **ETA**) – majority of site is TAN15 Flood Zone A. Localised flood risk along the ditches that form the upper Boverton Brook and Nant y Stepsau. With regards to works to these ditches, detailed schemes for the diversion of the upper Boverton Brook ditches and for the improvements to the upper Nant y Stepsau ditch-course will be developed and submitted to the Environment Agency Wales for agreement;
3. **FTA** – TAN15 Flood Zone A;
4. **SFA Tremains Farm** – TAN15 Flood Zone C2 and A. Buildings to be placed in Flood Zone A as confirmed by flood modelling;

5. **SFA** North of West Camp – TAN15 Flood Zone C2 and A. Buildings to be placed in Flood Zone A as confirmed by flood modelling;
6. **SFA** South West of Picketston – majority of site is TAN15 Flood Zone A. Localised flood risk along the ditches that form the upper Boverton Brook. With regards to works to this ditch, a detailed scheme will be developed and submitted to the Environment Agency Wales for agreement;
7. **SFA** Castleton – TAN15 Flood Zone A;
8. **ABP North** – TAN15 Flood Zone A;
9. **ABP South** – TAN15 Flood Zone A;
10. **NAR** majority of route is in TAN15 Flood Zone A. Appropriately designed crossing (abutments outside of Flood Zone C, soffit 600mm above the 0.1% AEP flood event) of the Llanmaes Brook is included for in the current proposals. Other watercourse crossings are relatively minor and will utilise culverts with capacities of the 1% AEP flood event plus 20% climate change allowance. It is proposed to divert the upper ditch-course of the Boverton Brook adjacent to the NAR at Picketston. As part of this scheme compensation storage will be provided for the encroachment of the NAR into part of the Boverton Brook's floodplain (Flood Zone C2). The scheme will ensure that the development does not cause any increase in flood risk downstream by allowing for appropriate attenuation of floodwater. Detailed schemes will be developed and submitted to the Environment Agency Wales for agreement;
11. **SAR** – TAN15 Flood Zone A; and
12. **Off-site road improvements** – St Athan junction: TAN15 Flood Zone A; Gileston Old Mill: TAN15 Flood Zone A and C1; and Waycock Cross: TAN15 Flood Zone A.

It will be necessary for detailed schemes for the proposed diversion of the upper Boverton Brook and for improvements to the Nant y Stepsau ditch-course (see 'DTC proposed drainage strategy' figure in **Appendix C**) as part of the DTC Picketston (and ETA) drainage to be further developed at detailed design stage and submitted to the Environment Agency Wales for agreement. This will ensure that the diversion of part of the upper Boverton Brook does not cause an increase to flood risk downstream in the Boverton Brook. Additionally the net transfer of part of the Boverton Brook catchment to the Nant y Stepsau will provide a small but important contribution to reducing flood risk in the Boverton Brook catchment. The reduction in catchment area (net transfer 34.5ha) will provide a small reduction to flood flows. The diversion of part of the upper Boverton Brook ditches, improvements to the Nant y Stepsau corridor as part of the DTC Picketston redevelopment and the proposed SuDS drainage improvements in general will upon redevelopment ensure that the existing localised surface water flooding along the Boverton to Eglwys Brewis road is improved.

6.1.2 Surface Water Management

Attenuation measures are proposed to ensure that surface water runoff from the site is not increased. This will mean that runoff from new areas of the development will be kept at greenfield rates, and that where areas are redeveloped, runoff that is at present not attenuated will be attenuated by the SuDS components of the new drainage system. A climate change allowance of 20% (30% for SFA areas) has also been included which will ensure that the drainage systems have sufficient capacity at present, and also due to any future increases in

rainfall intensity due to future climate change. Overall this will ensure that downstream flood risk from the development is not increased, and provide some betterment. **Section 5** alongside **Appendices B, C and D** provide further detail on the redeveloped sites sustainable drainage system.

The Sustainable Drainage System (SuDS) for the site has been developed with respect to each element of the development. A variety of types of SuDS are proposed, depending on the appropriateness within each element of the redevelopment. These range from underground pipe storage (ABP south and north, through to open attenuation basins (DTC ETA/sports area). Through the FCA and EIA process, the potential cumulative effects have been assessed in order to ensure that the redevelopment as a whole does not result in any detrimental impacts.

The final schemes for each component of the redevelopments SuDS will need to be developed at detailed design stage and submitted to the Environment Agency Wales for agreement.

7. Technical References

1. Boverton Brook (Environment Agency, 2001)
2. C697 - The SUDS Manual (CIRIA, 2007)
3. Estimating long return period floods (150-1000 years) - (Environment Agency, 2008)
4. Flood Estimation Guidelines – Operational Instruction (Environment Agency, 2008)
5. Flood Estimation Handbook (CEH Wallingford, 1999).
6. Flood Estimation Handbook CD ROM Version 2.0 (CEH Wallingford, 2007).
7. Flood Estimation Handbook WinFap-FEH CD ROM Version 2.0 (CEH Wallingford, 2007).
8. Improvements to the Flood Estimation Handbook statistical method – Operational Instruction (Environment Agency, 2008)
9. Open-Channel Hydraulics (Chow, V.T., 1959)
10. Sewers for Adoption 6th edition (WRC, 2006)
11. TAN15 Development and Flood Risk (WAG, 2004)

Appendix A

Composite Masterplan

Appendix B Site Photographs

Appendix C St Athan DTC - Surface Water Management Strategy

Appendix D ReFH Output
