Climate Change Analysis for the River Ray

Existing River Ray Model

The existing model covering the River Ray[1] was made available by the Environment Agency to inform the Level 1 SFRA for Swindon Borough Council. The data provided by the Environment Agency included simulations results for the 1% AEP (1 in 100 year) event with a standard percentage increase in river flow to account for the implications of climate change. This was applied as a 20% increase to fluvial flows based on previous climate change guidance[2].

Updated climate change modelling guidance was issued by the Environment Agency during February 2019[3]. This indicated that climate change should be considered through increasing allowances to peak river flow, determined by the location of a watercourse within a national network of River Basin Districts. The watercourses within the Swindon area fall within the Thames River Basin District where 25%, 35% and 70% allowances for climate change are identified most appropriate by the Environment Agency. As the existing River Ray model was completed during 2013, only a single 20% climate change allowance was included.

In the absence of flood extents for the updated climate change allowances, an assessment has been undertaken, as part of the Level 1 SFRA, to ascertain if using the 0.1% AEP (1 in 1,000 year) event as a surrogate is a suitable alternative. In order to determine the validity of using the 0.1% AEP flood as a proxy event, two methods were used to analyse the River Ray model.

1. Analysis of the stage-discharge relationship at nodes throughout the model has been undertaken, in accordance with the suggested approach set out in the guidance document published by the Environment Agency 'Flood Risk Assessment: Climate Change Allowances'[3].
2. Analysis of the inflows through the model has been undertaken to determine the relationship between the 1% AEP flood event and the 0.1% AEP flood event and how it compares to the 15%, 25%, 35% and 70% increases.

The results of these analyses are described below.

Method 1: Stage-Discharge analysis for River Ray

For the River Ray hydraulic model, output files were provided detailing the flows (discharge) and levels (stage) at each node for all simulated return periods. Outputs were available for events with AEPs of 20% 5%, 1%, 1% plus 20% allowance for climate change and 0.1%.

The River Ray rises at Wroughton, to the south of Swindon and flows in a northerly direction through the town. The 2013 River Ray model covers the extent of the watercourse from Mannington and Eastleaze, at the south western edge of Swindon, to the confluence of the Ray with the Thames at Cricklade, approximately 10.5km to the north.

The watercourse passes through a largely urbanised catchment and accordingly the modelled reach contains numerous culverts, bridges and structures likely to impact on flow and stage within the channel. The variable nature of the River Ray floodplain means that some sections of the watercourse will be flow limited (e.g. due to the presence of a constricting culvert at the upstream end) while in other sections the stage will be more limited (e.g. due to the presence of an open floodplain with significant floodwater storage capacity). The suitability of using the 0.1% AEP flood event as a proxy for climate change will therefore vary along the modelled reach.

[1] Work undertaken as part of the River Ray (Wilts) and Tributaries Flood Risk Mapping (2013), Hyder Consulting (UK) Ltd
[2] Climate Change Allowances for Planners, Guidance to Support the National Planning Policy Framework, September 2013
[3] https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances, accessed 12th April 2019.

In order to take account of this variation, five different reaches along the River Ray model were selected, each with a constriction to flow at either end (Figure 1Figure). The reaches analysed were as follows:

- Reach 1 – Mannington Recreation Ground – Redcliffe Street to Morris Street
- Reach 2 – Mannington Recreation Ground – Morris Street to Great Western Way
- Reach 3 – Rivermead / Swindon Sewage Treatment Works
- Reach 4 – Cheney Manor Industrial Estate / Moredon
- Reach 5 – Sparcells / Purton Road

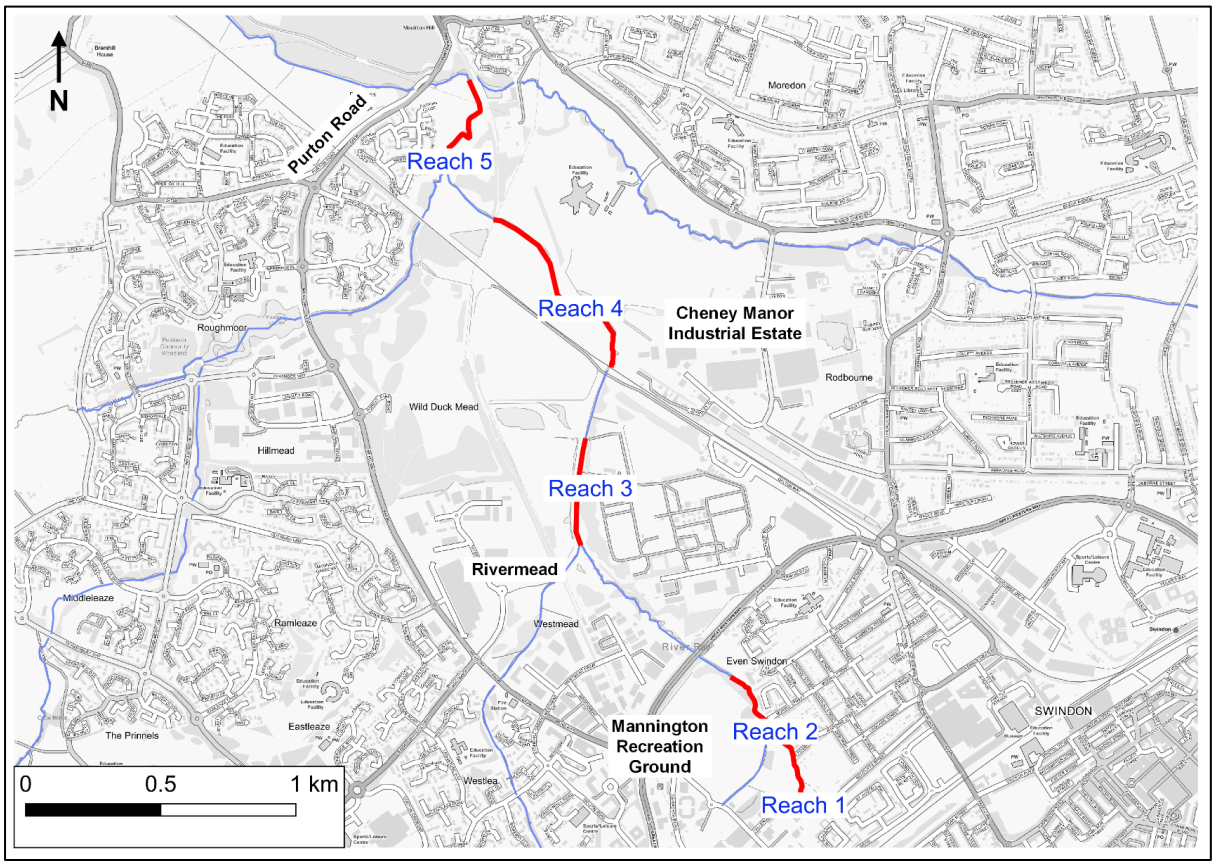


Figure 1: Location plan of river reaches

Data for stage and discharge at upstream and downstream nodes were plotted for all modelled scenarios and a trend line fitted to the stage-discharge relationship. Based on the existing modelled discharge values for the available return periods at various model nodes, stage values were extrapolated for the following climate change events, as set out in the guidance for the Thames River Basin District[4]:

- Central allowance (1% AEP event including 25%)
- Higher central (1% AEP event including 35%)
- Upper end (1% AEP event including 70%)

Model nodes within each of the Reaches are identified in Figure 2.

[4] https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances, accessed 12th April 2019.

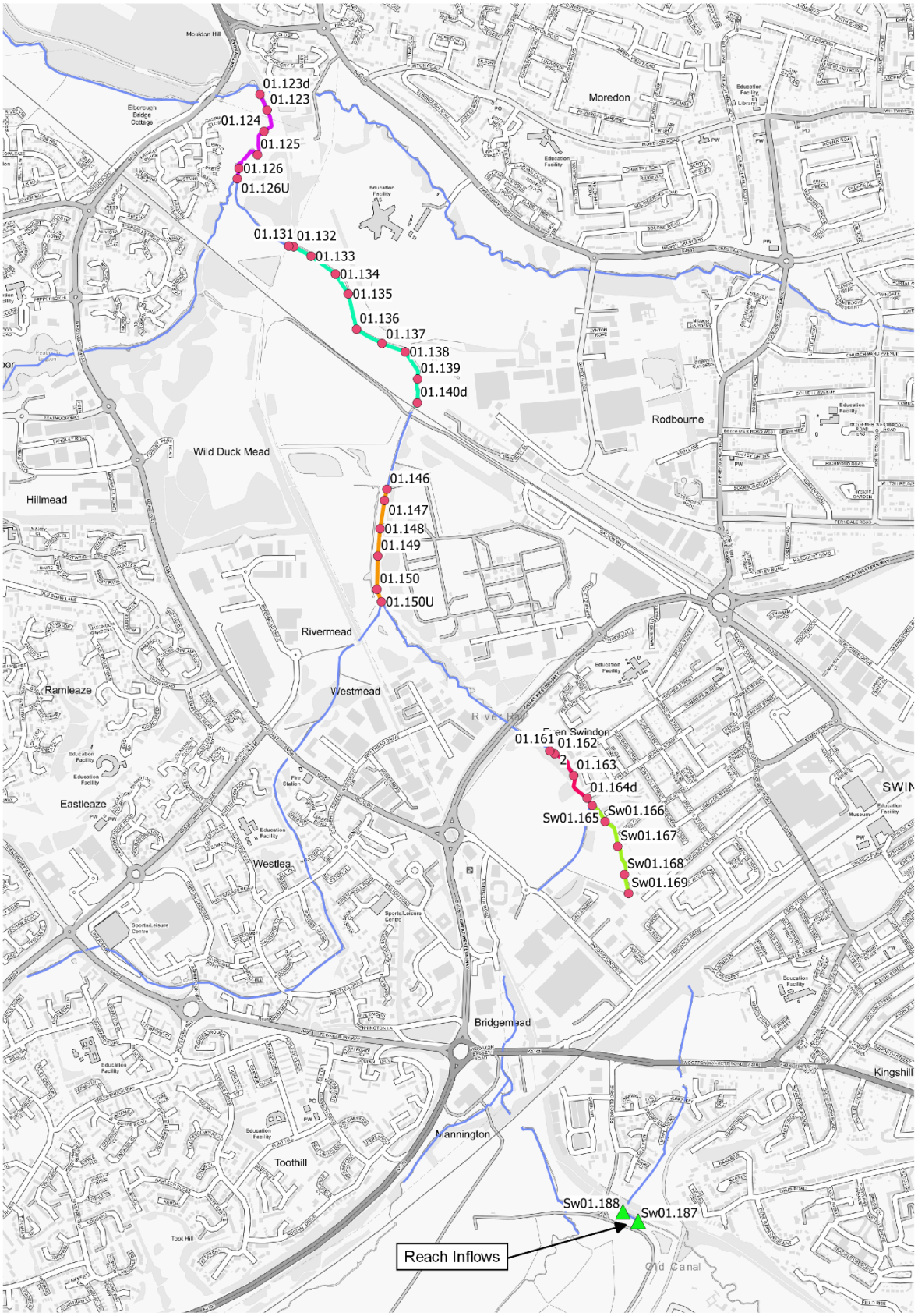


Figure 2: Location plan on model nodes

A graph showing the stage-discharge relationship for each node was produced as part of the analysis. An example is provided below (Figure 31) for a node along Reach 3 and full results provided in Table 1. This area is characterised by a large open floodplain which allows both flow and stage to increase, although there is some evidence of flattening of the flood growth curve for larger events. In this location, the 0.1% AEP event is a reasonable approximation of the additional extent of flooding which would be expected to occur due to climate change.

Figure 3: Stage-discharge relationship for the River Ray at node 01.150

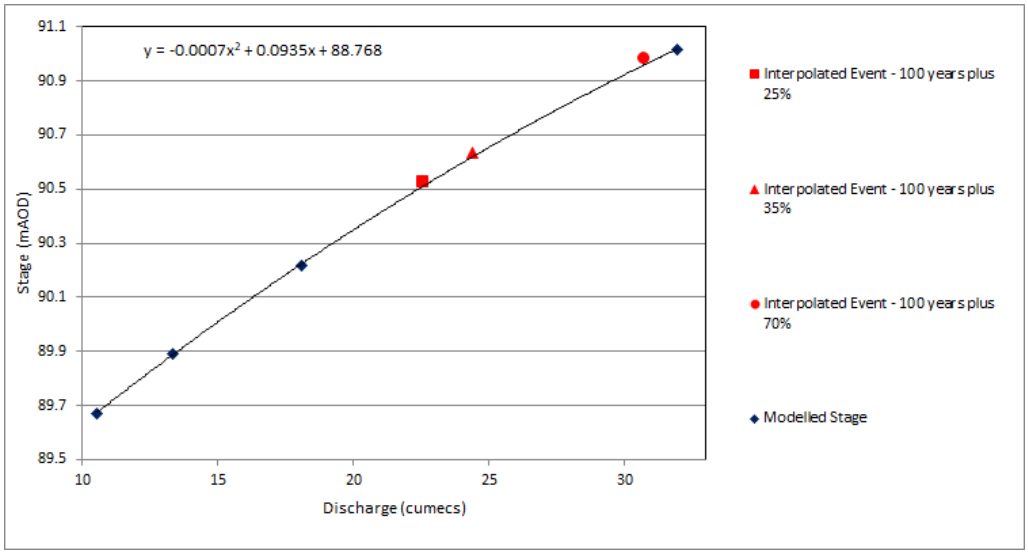


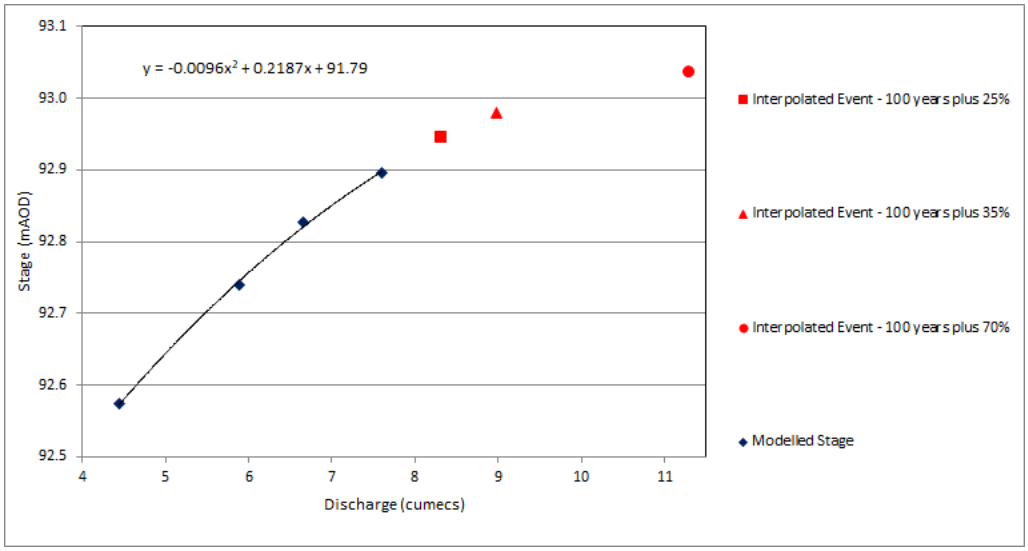
Table 1: Analysis of existing modelled flood water levels at node 01.150

Flood event AEP (years / percentage)	Model Scenarios Flow (m^3/s)	River Stage (mAOD)
5 / 20	10.559	89.671
20 / 5	13.323	89.893
100 / 1	18.077	90.219
1000 / 0.1	31.909	91.017
Extrapolated events		
1 in 100 year plus 25% climate change	22.596	90.523
1 in 100 year plus 35% climate change	24.404	90.633
1 in 100 year plus 70% climate change	30.731	90.980

In contrast, analysis of model results from node Sw01.168, towards the upstream extent of Reach 1, shows significant limiting of stage up to the 0.1% AEP event (see Figure 42). Peak modelled flow at this node increases from around 4.5 cumecs during the 20% AEP event, to 7.6 cumecs during the 0.1% AEP event. This 70% increase in peak modelled flow between the events does not translate into significant increases in peak stage at this location.

Theoretical adjustment for climate change of the 1% AEP flow in this location identifies flows in excess of the 0.1% AEP peak flow, which would suggest a significantly greater peak flood level. In practice however, the climate change flows will also be limited by factors such as channel and culvert capacity.

Figure 4: Stage Discharge Relationship for River Ray at node Sw01.168



This method for assessing the likely impacts of the updated climate change allowances is therefore considered not appropriate. This is further demonstrated when the maximum modelled flows for the 1% AEP and the 1% AEP plus 20% allowance for climate change events are compared (Table 2). When a 20% increase is applied to the inflows of the model this does not equate to a 20% increase in flow within all reaches of the watercourse due to flow routing. The far right column '*100yr+CC/100yr*' of Table 2 identifies the flow increase at each node when the two event results are compared. In Reaches 2 to 5 there is either a reduction in flow or a marginal increase. This further demonstrates the complexities of the model and this method is unlikely to identify reliable results.

Table 2: Extrapolated stage results and flow relationship

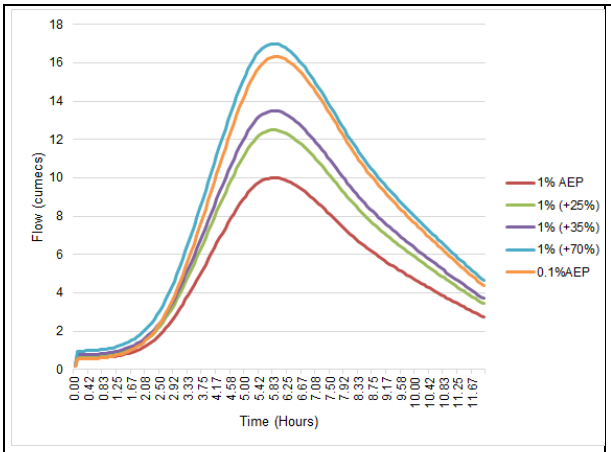
	5yrs event	20yrs Event	100yrs Event	100yrs Event (+CC)	1000yrs event	100yr+CC/100yr
Node	Max Flow (cumecs)	Max Flow (cumecs)	Max Flow (cumecs)	Max Flow (cumecs)	Max Flow (cumecs)	Flow increase
Reach 1						
Sw01.169	4.438	6.086	8.802	9.485	13.994	1.08
Sw01.168	4.446	5.887	6.652	6.816	7.609	1.02
Sw01.167	4.458	5.911	6.735	6.867	7.471	1.02
Sw01.166	4.464	5.026	6.144	5.869	7.148	0.96
Sw01.165	4.262	4.78	4.959	5.343	5.321	1.08
						1.02
Reach 2						
01.164d	9.637	11.364	11.335	11.405	11.316	1.01
01.163	9.013	9.841	9.955	9.989	10.183	1.00
01.162	9.029	9.864	10.079	10.064	12.986	1.00
01.161	9.033	9.694	9.869	9.848	10.066	1.00
Reach 3						
01.150U	10.55	13.096	15.445	15.642	15.783	1.01
01.150	10.559	13.323	18.077	17.754	31.909	0.98
01.149	10.568	13.343	18.1	17.735	31.629	0.98
01.148	10.579	13.357	17.812	17.517	24.821	0.98
01.147	10.585	13.306	15.674	15.954	34.594	1.02
01.146	10.588	13.312	17.902	17.503	18.47	0.98
Reach 4						
01.140d	10.618	13.354	17.972	17.491	26.031	0.97
01.139	10.627	13.37	17.984	17.487	26.027	0.97
01.138	10.64	13.38	18.013	17.496	26.061	0.97
01.137	10.647	13.401	18.036	17.503	26.082	0.97
01.136	10.658	13.415	18.066	17.510	26.126	0.97
01.135	10.672	13.432	18.099	17.519	26.14	0.97
01.134	10.681	13.447	18.122	17.525	24.815	0.97
01.133	10.692	13.461	18.148	17.532	25.554	0.97
01.132	10.697	13.473	18.165	17.537	24.035	0.97
01.131	10.702	13.475	18.169	17.539	26.79	0.97
Reach 5						
01.126U	14.267	16.378	17.292	16.998	34.74	0.98
01.126	14.203	16.452	17.471	17.081	24.815	0.98
01.125	14.234	16.302	17.433	16.985	19.216	0.97
01.124	12.02	12.379	12.656	12.712	12.94	1.00
01.123	12.832	13.357	13.951	13.848	14.388	0.99
01.123d	12.707	13.184	13.76	13.657	14.25	0.99

Method 2: Comparing Inflows

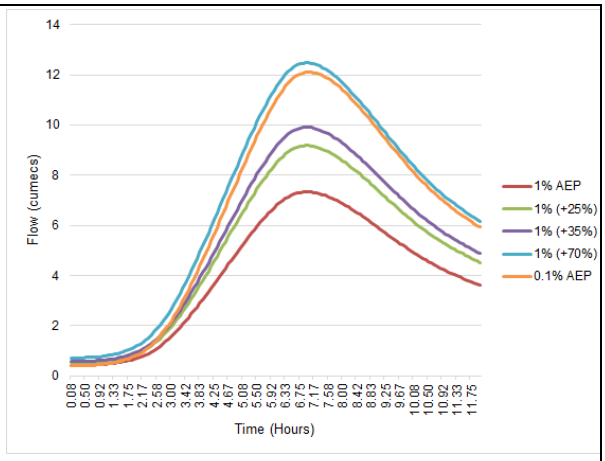
As an alternative method of assessing the suitability of using the 0.1% AEP flood outline as a proxy for the 1% AEP event including climate change, analysis of model inflows has also been undertaken. A total of six inflow nodes are connected to the studied reach of the River Ray model. By comparing 0.1% AEP hydrographs at each inflow node with adjusted versions of the 1% AEP flow hydrographs, an assessment can be completed.

In all cases the 0.1% AEP peak flow for the model is larger than the extrapolated 1% AEP plus 35% climate change peak flow (Figure 55). This gives some confidence in using the 0.1% AEP event as a proxy for climate change scenarios up to 35%, although this is likely to result in overstatement of flood risk. For development locations and proposals which require the 70% ('Upper End') climate change allowance to be considered, further hydraulic modelling will be required.

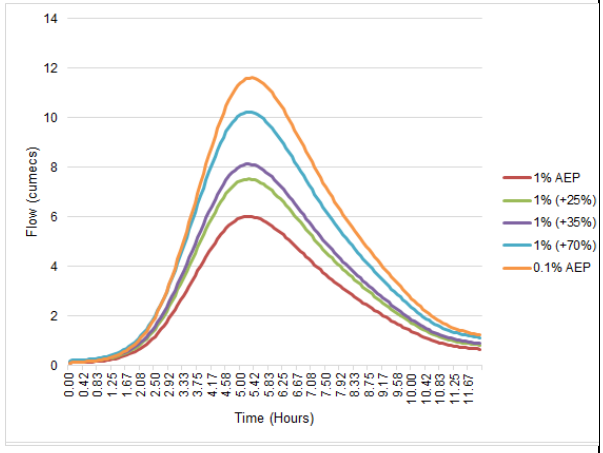
Figure 5: Inflow Hydrographs for 2013 River Ray Model with Adjustments for Climate Change



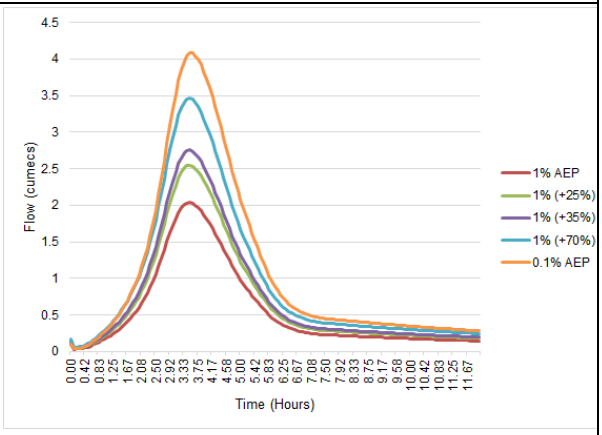
Inflow hydrograph at node Sw01.188: Inflow to Reach 1 from Rushey Platt area.



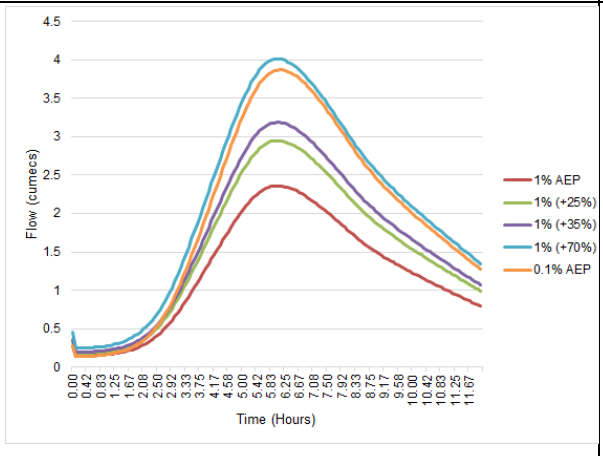
Inflow hydrograph at node 02.006: Inflow to Reach 2 from Mannington area.



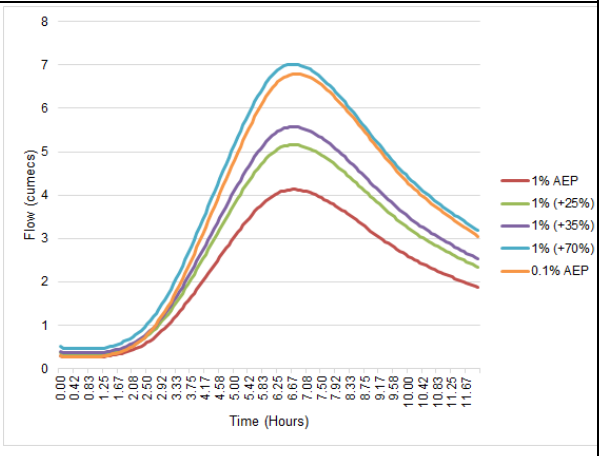
Inflow hydrograph at node 01.181: Inflow to Reach 2 from Mannington area.



Inflow hydrograph at node 11.039: urban runoff from Eastleaze / Freshbrook area to Reach 3



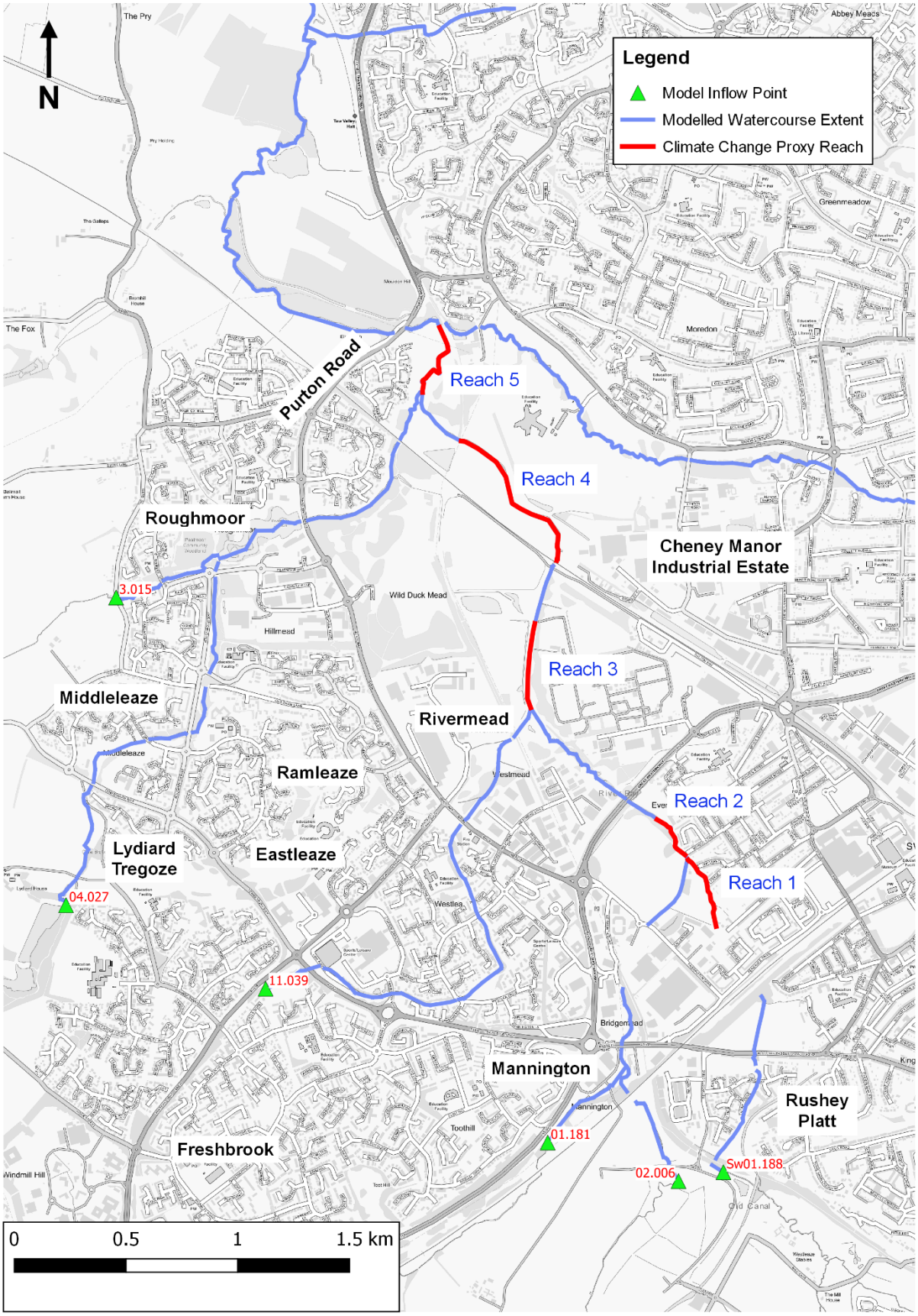
Inflow hydrograph at node 3.015: Urban and rural runoff from Roughmoor area to Reach 5.



Inflow hydrograph at node 04.027: Urban and rural runoff from Lydiard Tregoze / Middleleaze area to Reach 5.

Location of inflow points within the 2013 River Ray model are shown in Figure 66 overleaf.

Figure 6: 2013 River Ray Model inflow Locations



Conclusions

The impact of climate change on flood risk along the River Ray has been assessed in accordance with the approach set out in the guidance document published by the Environment Agency and through examination of modelled hydrograph inflows. This was to determine whether the modelled 0.1% AEP event flood outline is a good proxy for the 1% AEP flood when adjusted for climate change factors in line with the latest Environment Agency guidance.

Due to flow routing and complexities within the model, method 1 was considered an unreliable method for completing this assessment. Method 2 compared the hydrographs at each inflow node for the 1% AEP event and adjusted hydrographs for the climate change allowance events. The assessment concludes that in all cases the modelled 0.1% AEP event flood extent is likely to provide a good proxy for all events up to the 1% AEP plus 35% climate change allowance event. For development locations and proposals which require the 70% ('Upper End') climate change allowance to be considered, this was not the case and further hydraulic modelling will be required.

The Environment Agency stage/discharge comparison approach suggests that some reaches of the River Ray feature a complex relationship between flow and stage, due to interaction between flows, structures and the floodplain extents. For areas identified in Flood Zone 2, additional assessment and/or modelling will be necessary at the site specific FRA stage, in order to determine the actual impact of climate change on flood levels and extents.

It is anticipated that there will be greater emphasis for site specific Flood Risk Assessments to include additional modelling scenarios to determine the future flood risk, with respect to climate change, where existing hydraulic modelling data is not available.

It is recommended that developers contact the Environment Agency at the pre-planning application stage to confirm a site-specific flood risk assessment approach, on a case by case basis.