Session 3 Paper 10 – Should we design to rainfall return periods or flood return periods?

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1 INTRODUCTION

1.1 Background

Flooding to properties can occur due to a number of factors but all they want is to not be flooded again from any source of flow. Traditionally within the water industry, urban drainage modelling concentrates on the use of rainfall in order to try and replicate flooding and in some circumstances does not take account of any other factors which may cause flooding. This could mean that solutions which are built to protect against flooding may not work.

The other main factors that can contribute to the flow in the pipe apart from dry weather flows and rainfall are groundwater flows, river levels or tide levels. These can have a different critical duration to the rainfall and can be independent of the rainfall. This can mean to take account of them to protect against flooding can be difficult.

This paper will examine how rainfall return periods are currently modelled and then will go on to look at flood return periods and how these can be included in the modelling of proposed solutions to flooding problems in the catchment. As part of putting this paper together information was gathered from the wider industry with the use of a survey and the results of this have been included where appropriate.

Within the questionnaire people were asked whether they were using rainfall return periods or flood return periods. The results from this are shown in Figure 1.1 and shows that the majority of people are modelling to rainfall return periods. Figure 1.2 shows that when the question was changed to ask what should be used the results show that the majority of people think flood return period should be used. This shows that within the industry there is feeling that solutions to flooding should be designed to flood return periods rather than rainfall return periods. The results shown are from 35 respondents.

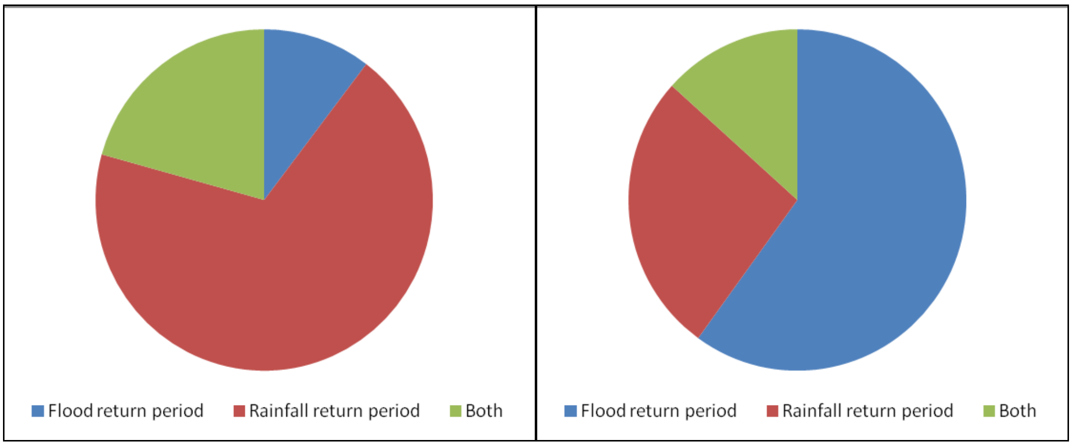

Figure 1.1: Current return period design to; Figure 1.2: Way we should be designing

2 DEFINITIONS

In order to understand the difference between rainfall return periods and flood return period it is first important to understand what is the definition of these two terms. In the questionnaire one of the questions that was asked was what people's definition of these terms was. In the responses there were several different definitions for these terms. From all of the possible definitions the two below best describe rainfall return period and flood return period.

Rainfall return period is the frequency of a certain magnitude of rainfall.

Flood return period is how frequently flooding occurs at a given location. The flooding that occurs is not just caused by rainfall but is also influenced by many other factors. Some of these will be due to serviceability issues including blockage or pump failure while others will be due to hydrological inflows other than rainfall which could include groundwater infiltration, river or tide levels.

3 RAINFALL RETURN PERIODS

3.1 Current Methodologies

3.1.1 Design Storms

A design storm is an idealised storm which is derived from the Flood Estimation Handbook (FEH) that was developed by the Centre for Ecology and Hydrology (CEH). It has been used in river modelling for a number of years to generate river flows. Within Urban Drainage modelling it is used to generate the rainfall to generate the inflows into the sewer system. It is possible to get different rainfall profiles for the summer and winter. Figure 3.1 shows the rainfall profiles for summer and winter storms.

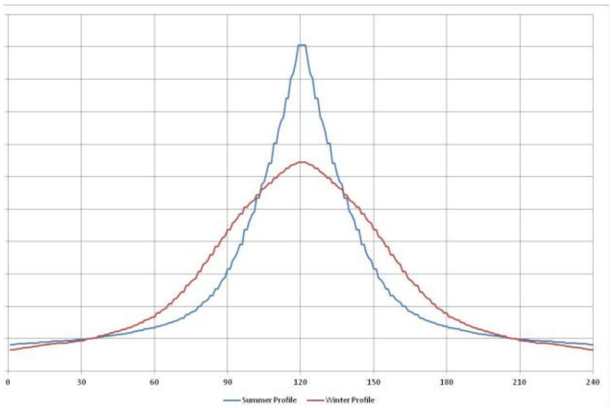

Figure 3.1: Summer and winter profiles

This has been the standard method which is used when looking at flows within the sewer. However, within the calculations there are a number of conservatisms which can lead to potentially conservative solutions. As an alternative to design storms there are now moves away from just design storms and using Time Series Rainfall (TSR) as well to determine how solutions will operate.

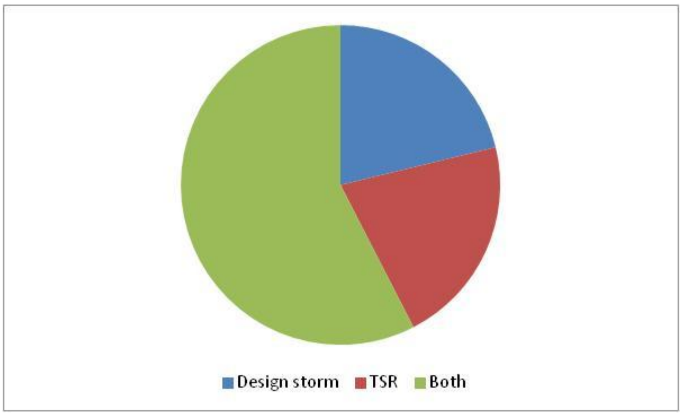

Figure 3.2: Use of TSR or design storms

In the questionnaire it was asked whether people use design storms or TSR. The results of this are shown in Figure 3.2. This shows that actually most people are using a combination of both methodologies and there is an even number of people using design storms and TSR. In the responses it was mentioned that the use of design storms is normally a client requirement.

3.1.2 TSR

Timeseries Rainfall (TSR) is a continuous rainfall set which is generated using historic rainfall and is normally performed using StormPac software. The rainfall that is generated is based on the statistics of the historical storms in order to generate a series of rainfall typical of a particular locality. Within this new series of rainfall there are storms of different return periods and the data matches the statistics of the return periods that occurred previously. These forms of rainfall are mainly used for water quality assessments when looking at Combined Sewer Overflows (CSOs) or discharges from storm tanks at Sewage Treatment Works (STW). Recently these types of rainfall are now being used to test designs which were previously done with design storms to determine how they might work once they are built. These TSRs are usually over 30 years although there is now a move to try and generate longer TSRs including up to 100 years however the accuracy of these is likely to be less than 30 years due to the lack of reliable information over this length of time.

3.1.3 Return periods used in design

When looking at solutions to flooding different clients have a variety of different return periods which they work to. For water companies the designs are generally carried out to a 1 in 30 or 1 in 40 year for internal flooding and a 1 in 10 or 1 in 20 for external flooding. Environment Agency projects are designed to a 1 in 100 or 1 in 200 year standard. For the highways agency the standard required is only a 1 in 5 or 1 in 10 year. As there is such a large difference across the industry this can cause issues when looking at modelling to ensure all inflows are included.

3.1.4 Climate Change

Climate change within the water industry is dealt with in a number of different ways and there is no consistent methodology. Part of this is due to the differences which are predicted to occur across the country due to climate change but also it is due to the differences in the understanding of the current guidance of climate change. Allowance for climate change is mainly achieved by adjusting the design storms rather than the TSRs. However, work is being undertaken to see how climate change could be taken account with TSR analysis.

For design storms a common approach is to multiply all of the rainfall by a constant amount. However, there are some water companies where the intensity of the summer storms are changed without increasing the overall volume and the volume of the winter storms is increased without increasing the peak intensity. All of the different methodologies are potentially valid because of the uncertainty of what will occur in the future.

Recent research has been undertaken looking at the different scenarios which are in UKCIP09 to generate a time series. The issues are that there are different scenarios and therefore different profiles will be generated and several model runs would be required. Analysing the results is time consuming and due to obligation dates to resolve flooding this would not always be acceptable. Figure 3.3 shows the medium emissions scenario results which show wetter winters and drier summers.

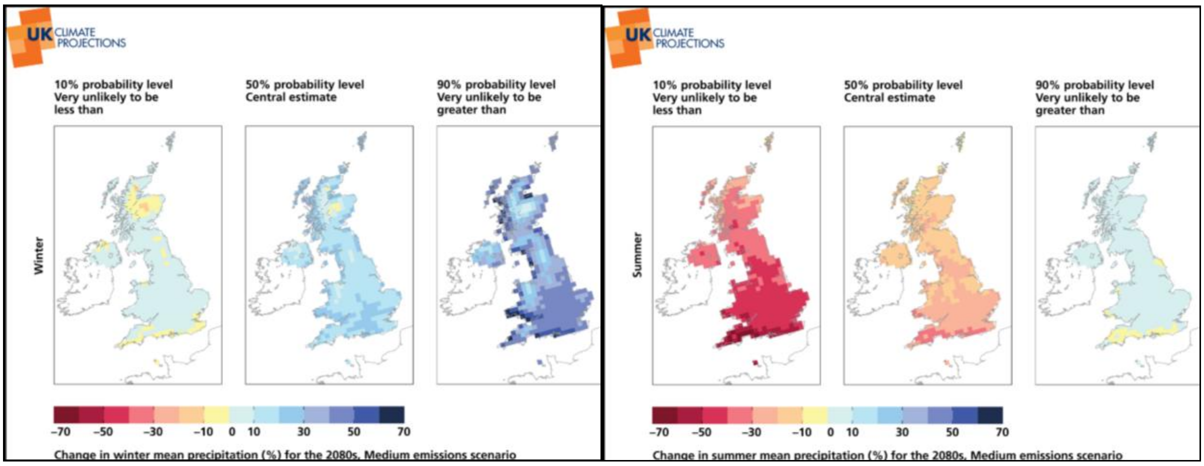

Figure 3.3: Predictions for the rainfall in the medium emissions scenario

One approach when looking at TSRs is to use delta change methodology, which would involve multiplying the historic rainfall by a factor. The factor which is used is based on the rate of change that is seen between the future and baseline General Circulation Models (GCMs). This methodology has many pitfalls as it only changes the mean, maximum and minimum and leaves the range and variability. There is also the same spatial variability and no effect of the number of wet days or the size of the extreme events is taken into account.

4 FLOOD RETURN PERIODS

4.1 Boundary conditions to include

Figure 4.1 shows the various questionnaire responses as to the other potential boundary conditions which should be included. In the responses it was also mentioned that the boundary conditions that should be included will vary depending on location.

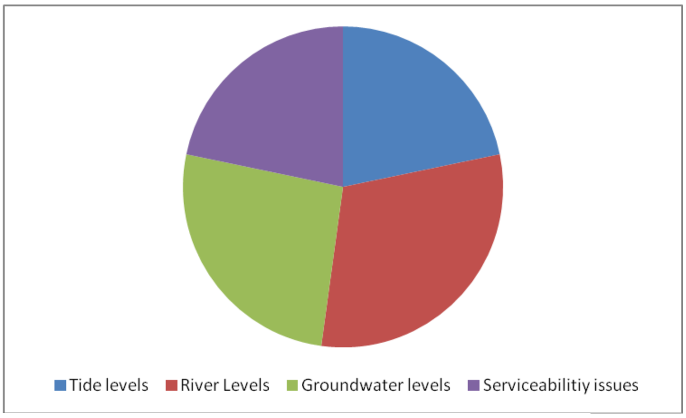

Figure 4.1: Various boundary conditions

4.2 Groundwater infiltration

4.2.1 Data available

Groundwater levels are modelled by the Environment Agency (EA) to look at the abstraction of flows from the aquifers. Within the Anglian Water region the EA have eight models which cover a large proportion of the area which the water company serve. Figure 4.2 shows how these models tie into the sewer models within this region. There is a large area which stretches from The Wash across to Hampshire which has no models due to the lack of abstraction which occurs in this area. A review of the Winter Rainfall Acceptance Potential (WRAP) map shows that this area is Soil Type 3 and 4 which would limit the amount of infiltration into the aquifer as these are more clayey soils.

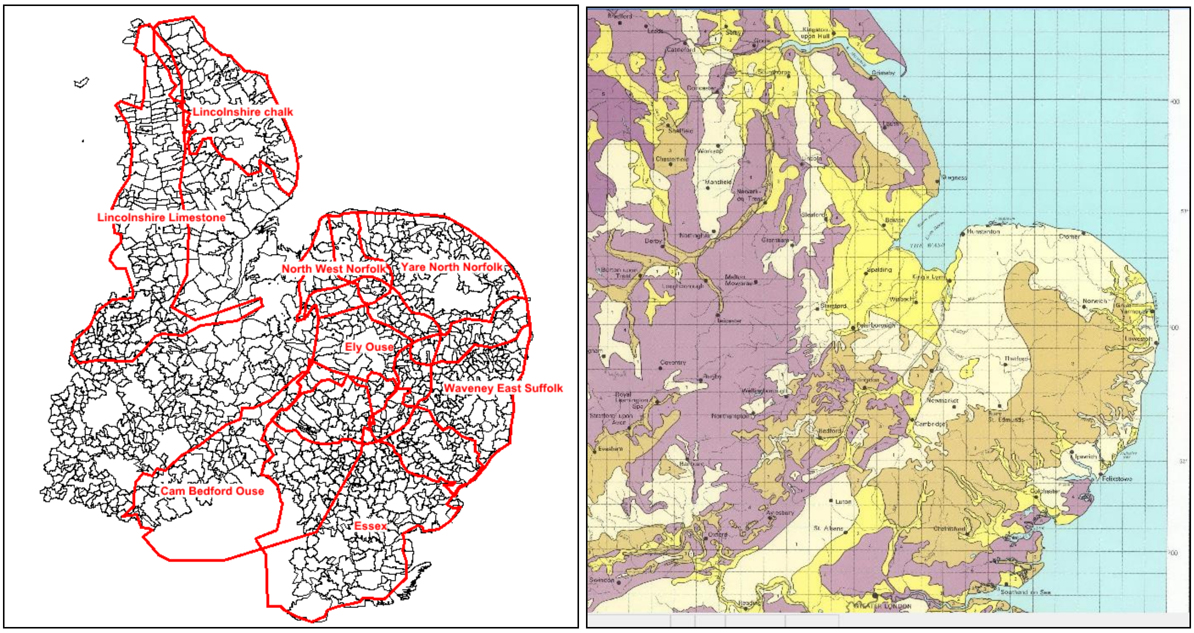

Figure 4.2 – Location of groundwater models compared to sewer catchments in the Anglian Water region and an extract from the WRAP map

The data from these models can be extracted in two different ways; the first way is the groundwater levels at a specific time which could be the minimum, maximum or average or the second way as a continuous hydrograph for the full model run. With the levels it is possible to generate a surface which can compared to the inverts of the pipes within a sewer system. For a catchment in the Anglian Region this has been done and is shown in Figure 4.3.

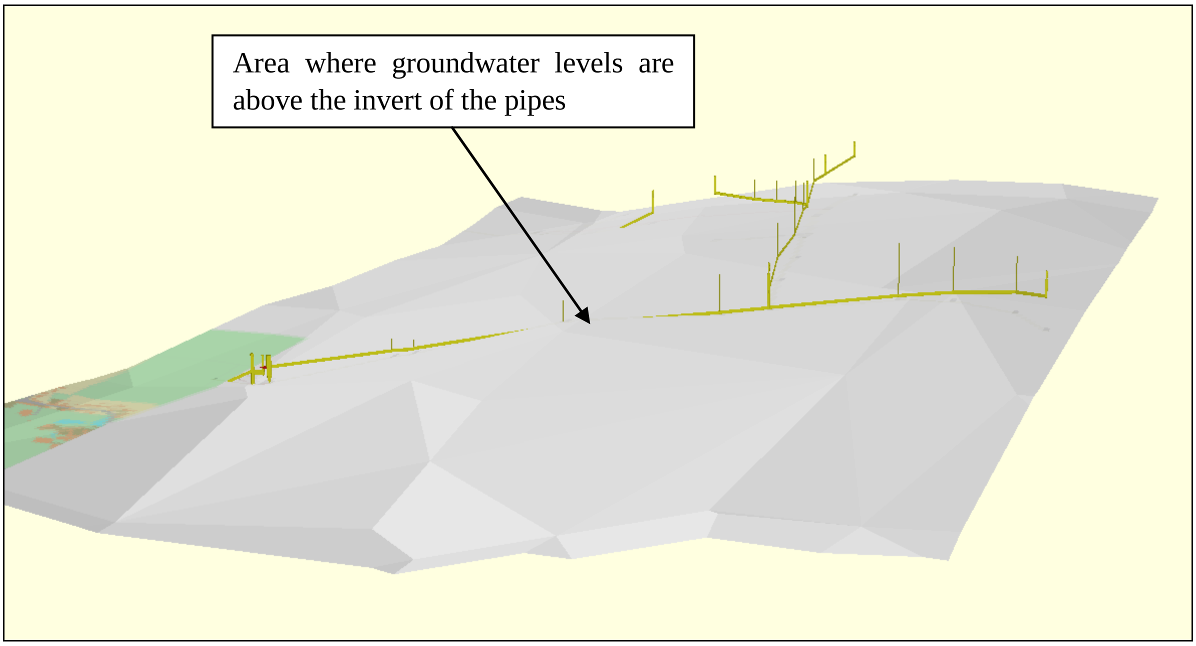

Figure 4.3 – Comparison of maximum groundwater levels to pipe inverts

This can be used to give an understanding of where the groundwater may be above the invert levels of the pipe and could enter the pipe system but not how often these levels are achieved. From the model of this area a graph (Figure 4.4) of the groundwater levels over the time can be produced which can show how often the level has been above the invert of the pipe.

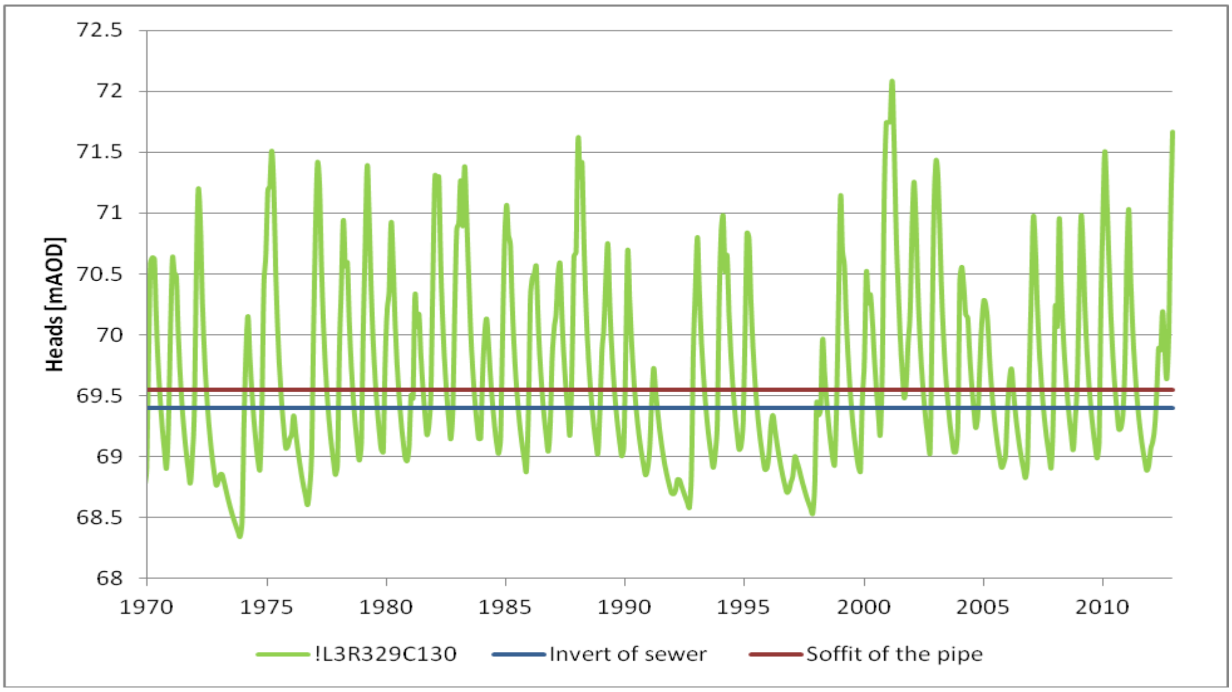

Figure 4.4: Groundwater level against pipe invert level over the full range of the model

At this location the groundwater level is above the invert more than 300 months over this time range but this does not necessarily mean that water is able to enter the pipe in this area as this will be affected by condition of the pipe and the bedding of the pipe which may not be known for these areas.

If specific years are looked at then it is possible to see that there is a large variability between years. Figure 4.5 shows the groundwater levels against the pipe invert levels for two years, a dry year and a wet year and how this compares to the pipe level.

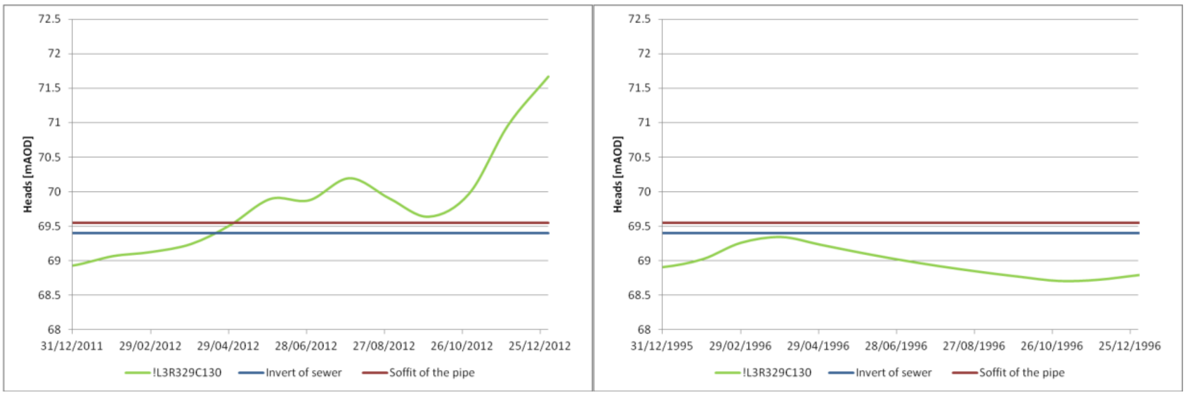

Figure 4.5 – Groundwater levels for a wet and dry year

4.2.2 Use within modelling

When modelling of groundwater levels is undertaken it can be modelled in a number of different ways. These are:

- Varying inflow over time;
- Constant inflow over time;
- Large routing value;
- Groundwater infiltration module.

The use of varying data is more appropriate if the model is being run with a TSR as the groundwater levels will not vary quickly enough over the normal short storms which are used for design storms. With a constant inflow this will need to be different depending on whether it is summer storms or winter storms being looking at. This is because the highest groundwater levels will occur during winter months but generally flooding from a sewer system is worse during the summer months when there is high intensity rainfall. A large routing value can be used but it is likely that any influence of the groundwater levels cannot be modelled this way as the value required will be very high and outside the data range that was used to develop the runoff model. The groundwater infiltration module within InfoWorks can be used to represent the varying levels but a large amount of data is required to determine the parameters. This needs to be at least one years worth which is a lot more than what is normally collected e.g. 12 weeks or until three storms have been recorded.

For all of these methods there is no influence of climate change allowed for. This is because all of these methods are based on trying to match historic levels of infiltration rather than predicting what may occur in the future.

4.3 River levels

4.3.1 Data available

Across the country there is a network of river gauging stations which are continuously monitoring the river levels and are used to by the Environment Agency to assess flood risk. For the majority of these locations the Environment Agency has calculated various return periods levels. Figure 4.6 shows the distribution of gauging stations across the Anglian Region.

4.3.2 Use within modelling

Within modelling it is possible to represent the river in different ways. The first is a constant river level equal to a certain return period. The second method is to use a level which varies over time and the third method is to include the river in the model of the sewer system in order to see how it varies over time. In terms of how the flow will actually enter the sewer system, this is potentially restricted if there is an outfall with a flap valve or if there has been out of bank flow before it enters the sewer system. If the level is in bank but above the level of the outfall then using a level hydrograph is the most appropriate method. However, if the river level is out of bank and there is potential for the flow to enter manholes then the use of either a 2D model to represent this or a model which includes both the river and sewer system is the most appropriate.

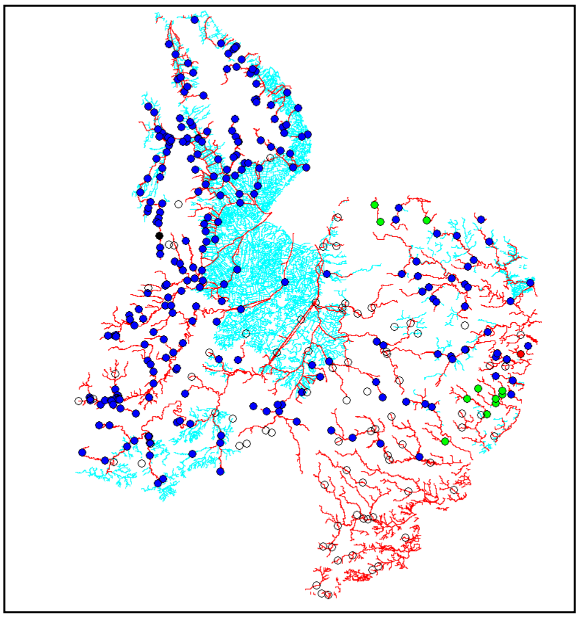

Figure 4.6: Distribution of river gauges across the Anglian Water region

4.4 Tidal levels

4.4.1 Data available

Tidal levels are recorded around the coast and these have a sinusoidal curve which varies over the day between high and low tides. Also, across 28 days there are variations in the tide levels from neap to spring tides. On top of the standard tidal curve there is also the potential for a tidal surge. These surges are not related to the rainfall in the area but due to increases in winds pushing the water towards the land. Figure 4.7 shows the variation in the tidal levels over time and also the effect of the surge on the peak water levels.

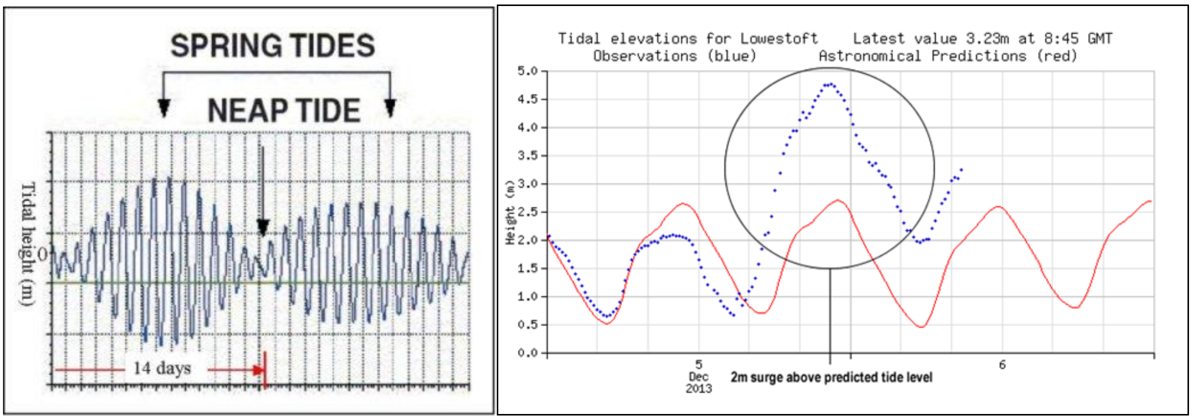

Figure 4.7: Differences in tide levels over time and the effect of a tidal surge

4.4.2 Use within modelling

Adding tidal levels to a model is similar to that of adding a river level to a model and has the same issues in terms of where the peak levels are in relation to the overflow levels and the ground levels in the area. With tidal levels there would be more of an issue in terms of time due to the fact the tidal levels continue to go up and down and are not related to rainfall. It would be possible to match the diurnal pattern but not the tidal surges.

4.5 Other factors

Within sewers there are a number of other factors which can cause flooding to occur. These are mainly related to serviceability issues including; blockage, pump failure and screen blinding.

These occur due to a number of different reasons and are not related to rainfall which makes them difficult to predict or to replicate. Within the solutions the models are run with everything working as it should and they do not take account of any failures within the system. This does mean that there is still a risk of flooding occurring even after a solution has been implemented due to a serviceability issue but should designs be taking account of failure? In order to understand how this may affect the solutions which are developed it may become necessary to carry out active management of the catchment. Modelling can be used to provide information on areas where this could be targeted but until they occur it may not be accurate.

Within modelling these serviceability issues can only be taken into account when trying to replicate flooding which has happened in the past. This means that although these are known to occur they are not included when looking at flood return periods.

5 JOINT PROBABILITY

5.1 Definition

Joint probability is the probability of event Y occurring at the same time as event X. This means for flooding that the probability of the two factors are multiplied together,

5.2 Issues with this method

The issue with this method is that the probability of two or more of these factors occurring at the same time can easily mean that the event being looked at is greater than that is required to be designed to. For instance on a simplistic level, a 1 in 5 year rainfall event and a 1 in 10 river level occurring at the same time has a joint probability of 1 in 50 which is above the design standard for sewers.

As well as looking at the probability of the two events the timing of two events needs to be looked at. This is because peak flows from the sewer will normally occur before peak river levels and these will occur before the ground water peaks. Tide levels are not related to rainfall and therefore could occur at any time and should be taken into account where there is an influence from this source. Figure 5.1 shows the differences in the critical durations between the sewer system and the river.

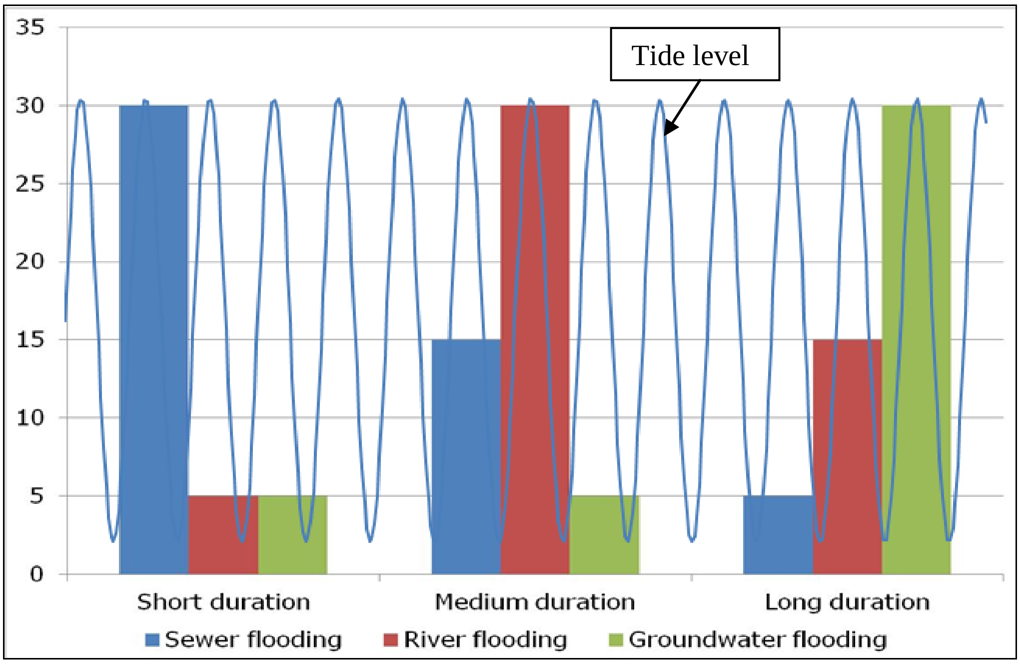

Figure 5.1: Influence of different flows on the flooding observed

From this graph the probability of these peaking at the same time is very unlikely. This would mean a lower return period on the river level with a higher return period on the sewer system. One of the critical things when looking at this is to consider whether the same rainfall is contributing to the increases on both systems. A catchment at the upstream end of the river is likely to respond to the same rainfall. The further downstream the watercourse the catchment is located the less likely that the same rainfall will be affecting the sewer and the river at the same time. Where this is considered then levels from the Environment Agency on the gauging station can be obtained to determine if high river levels occurred when areas have flooded previously,

When looking at the combination of groundwater and sewer flooding this can be more difficult as groundwater is likely to respond slowly over time and it make take several back to back storms for the groundwater to be causing an inflow into the sewer system. With the groundwater levels it is more likely that the highest levels will occur over the winter rather than summer and it may be necessary to have different levels of infiltration depending on whether summer storms or winter storms are being looked at.

Tide levels are not related to rainfall and are completely independent of the rainfall. This means that if tide levels could be affecting the amount of flooding then it will necessary to look at the impact of a tidal surge of a return period up to a 30 year to ensure solutions will still work if the rainfall occurs at the same time as the high tide. However, the joint probability may be very low.

6 SUMMARY

From reviewing the information which is available solutions should be checked to ensure that they still work in flood return periods including all potential influences. However, it is important to remember that the timing of these influences can be independent and the chance of them occurring at the same time needs to be analysed. This can be done by reviewing the historical information to determine the impact of all of the influences which caused the flooding.

From reviewing the data there is enough information in order to model flood return periods. The data should not be used without reviewing how the flows may be able to enter the sewer system. The timing of any potential inflows needs to be assessed.

In looking into this a further a question that requires answering is whether water companies should be modelling to flood return periods. Within Sewers for Adoption it states that sewer systems should be designed to a 30 year return period. It does not state whether this is a rainfall return period or flood return periods, however it is understood that it was meant to be rainfall return period. There is now with more information the potential to go to flood return periods but is this beyond what water companies are funded for?

7 ACKNOWLEDGEMENTS

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