MATH3001: Project in Mathematics

Flood Analysis: Assessing and communicating mitigation of river floods to policy makers and the general public

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Contents

1 Introduction

Flooding in the United Kingdom in recent years has led to major destruction of houses, the environment and government properties. Many people throughout the country have lost homes, money and occasionally even lives. This report will attempt to investigate some of the major floods the UK has experienced over the last two decades and attempt to provide river-mitigation solutions apt to the environment, economy and aesthetics of the surrounding area and council.

This project will be attempting to investigate:

- What types of flood mitigation strategies are available and how they work.
- What FEV (flood excess volume) is and how it is estimated, using rating equations given by the Environmental Agency under the 'Freedom of Information Act', and describe how this model can be used to mitigate flooding.
- The Boxing Day 2015 floods the River Aire, Leeds, the River Calder, Mytholmroyd and the June 2007 flood of the River Don, Hadfields. This will be done as an exercise to familiarize oneself with the coding skills and the data collection methods needed to investigate other river floods. Knowledge of estimated FEV will be applied and examples of potential flood mitigation strategies will be discussed. This will be an attempt to verify and recreate data completed originally by Onno B and Thomas Kent.
- The Boxing Day 2015 flood of the River Wharfe, Addingham. This will be primary research, where FEV will be estimated and flood mitigation strategies will be discussed which are most apt to the requirements of the river and surrounding council.
- What current strategies are being set out by local councils and suggesting alternatives that may be more cost/environmentally effective.

2 Flood Excess Volume

2.1 Return Period

Flood Excess Volume (FEV) is the estimated volume of water that a river has flooded by. Thus, the FEV is the approximate volume of excess water needed to be contained or mitigated in order to prevent a flood of the same size within a given return period. A return period is the inverse probability (given as a percentage) of the estimated time period between similarly large events, in this case flooding. Commonly misconstrued, this is not to say that if a return flood period is 100 years, that the next flood of the same magnitude would occur 100 years later, but rather that there is a 0.01 probability that a similar flood could occur any given year succeeding this.

2.2 Calculation

To calculate the FEV of a flood, first data must be collected and analyzed from the Environmental Agency. They analyze the river level (height) against a timestamp at 15 minute intervals across

hundreds of gauge stations over the country. For each individual gauge station, it is possible to estimate the threshold level of the river (Ht), measured in m. This value can be estimated many different ways, from social media time stamped photos to online live resources such as (www.gaugemap.com).

- River Mitigation: Meaning 'reducing the risk or loss of occurrence of a specific event'[1] so in the case of rivers reducing the occurrence of flooding.
- Stage: Meaning the height of the river. The data provided for this was requested from the Environmental Agency[2].
- Flood Excess Volume: (F.E.V.) The estimated volume of water that the river has flooded by ie. the volume of excess water needed to be contained in order to prevent the flood.
- H_t: The threshold stage, or the stage at which the river begins to flood, estimated by visual aids and government recommendations, such as www.gaugemap.co.uk[3].
- H_m: The mean stage of the river providing the river has already flooded, given as:

$$\frac{\Sigma_{i=1}^{n} h_i}{n}, \forall h_i \geq h_t$$

- Rating Curve: The Environmental Agency provide figures at each individual gauge station across the country to give a general rating equation, given as:

$$\mathbf{Q}(h) = c(h-a)^b$$

  where '$\mathbf{Q}$' is the flow rate of the river, and a, b and c are values given by the environmental agency. The agency also provides upper and lower limits at certain stages, and thus if you run an equally increasing set of h values through '$\mathbf{Q}$(h)' you compile a rating curve specific to that gauge station, as shown in the top left quadrant of figure 1, below.

[1] Economic Times: Mitigation, https://economictimes.indiatimes.com/definition/mitigation, 2018.
[2] enquiries@environment-agency.gov.uk.
[3] Shoothill LTD, https://www.gaugemap.co.uk, 2014-2018.

3 Analysis of Aire, Don and Calder

3.1 River Aire

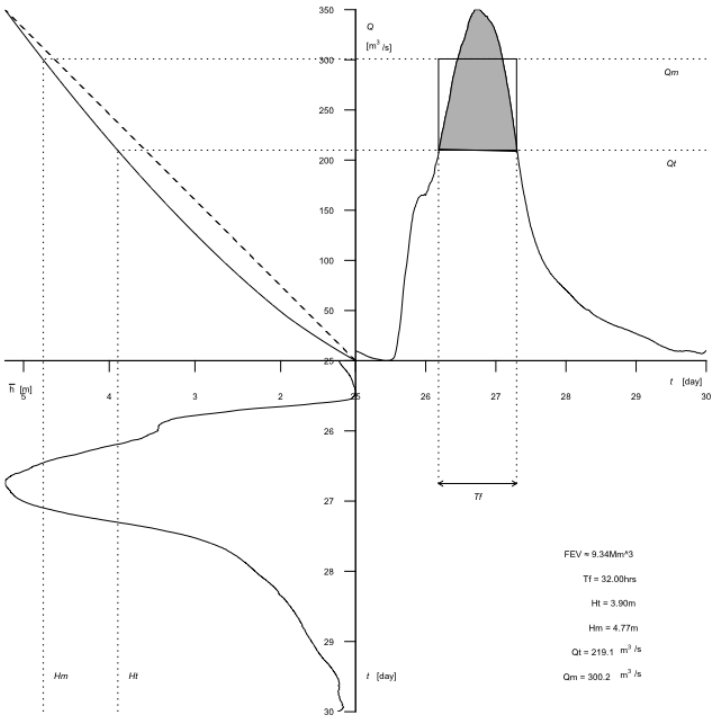

Figure 1: Quadrant plot depicting the Boxing Day 2015 Floods of the River Aire at Armley, Leeds. The data used was compiled and requested for from the Environmental Agency.

3.2 Explanation of the quadrant plot

Above in figure one is a quadrant graph representation of the Boxing Day 2015 Floods of the River Aire at Armley Gauge Station, in Leeds. As described above, the top left quadrant is the rating curve ($\mathbf{Q}$(h)), with H_t and H_m calculated respectively. From these two values, it is easy to evaluate Q_t and Q_m, with Q_t=$\mathbf{Q}(H_t)$, and Q_m=$\mathbf{Q}(H_m)$. From the stage and time data, and the rating curve, we can estimate the flow rate given the time, depicted in the top right quadrant of the graph. The shaded area of the graph represents the data where $\mathbf{h}\geq \mathrm{H}_t$, and thus $\mathbf{Q}\geq \mathrm{Q}_t$, so is an estimation of the volume of water in which the Aire burst its banks, or the F.E.V. The square box is an estimation of the F.E.V. (the shaded area), estimated by evaluating:

$$\mathbf{F.E.V.} \approx \ T_f(Q_m - Q_t)$$

where T_f is the time span in which $\mathbf{Q}\geq \mathrm{Q}_t$. We can then use this estimation to evaluate the effectiveness of specific mitigation strategies on the Aire. For the Aire we can see the F.E.V. is $\approx 9.25\mathrm{Mm}^3$, so this is approximately the volume of water that has burst the banks of the Aire at Armley. Later in the

investigation, we will use this F.E.V. to justify which mitigation or collection of mitigation strategies could be used by the council to combat a similar extreme flood in the future.

4 Analysis of the Wharfe

4.1 Background

The River Wharfe is a Yorkshire river, acting as a border for North and West Yorkshire for most of its legnth[4]. Its approximately 65 miles long, the 21st longest in the UK[5], and passes through many towns including Ilkley, Otley and Tadcaster. Like the floods of the Aire and Calder, the Wharfe flooded heavily on Boxing Day 2015, causes mass destruction to property and infrastructure. In this report, we will be primarily focusing on the gauge stations in the town of Otley, and the town of Addingham, approximately 9 miles upstream. After the destruction caused by the 2015 floods, the local council announced a £2 million flood alleviation scheme for Otley, to be completed in 2019/2020[6]. For this reason, it seemed like analyzing the river at this point would be potent, and hopefully give added insight onto the scheme that has been set up prior to completion.

[4]Wikipedia, River Wharfe, https://en.wikipedia.org/wiki/River$_{W}harfe, November$2018.

[5]Owen, Sue; Pooley, Colin; Park, Chris; Clark, Gordon; Watson, Nigel (2005). "Appendix 2". Rivers and the British landscape. Lancaster: Carnegie House. p. 232. ISBN 978-1-85936-120-7.

[6]Leeds.gov.uk, Otley Flood Alleviation Scheme, https://www.leeds.gov.uk/parking-roads-and-travel/otley-flood-alleviation-scheme, 2018.

4.2 River Wharfe quadrant plot

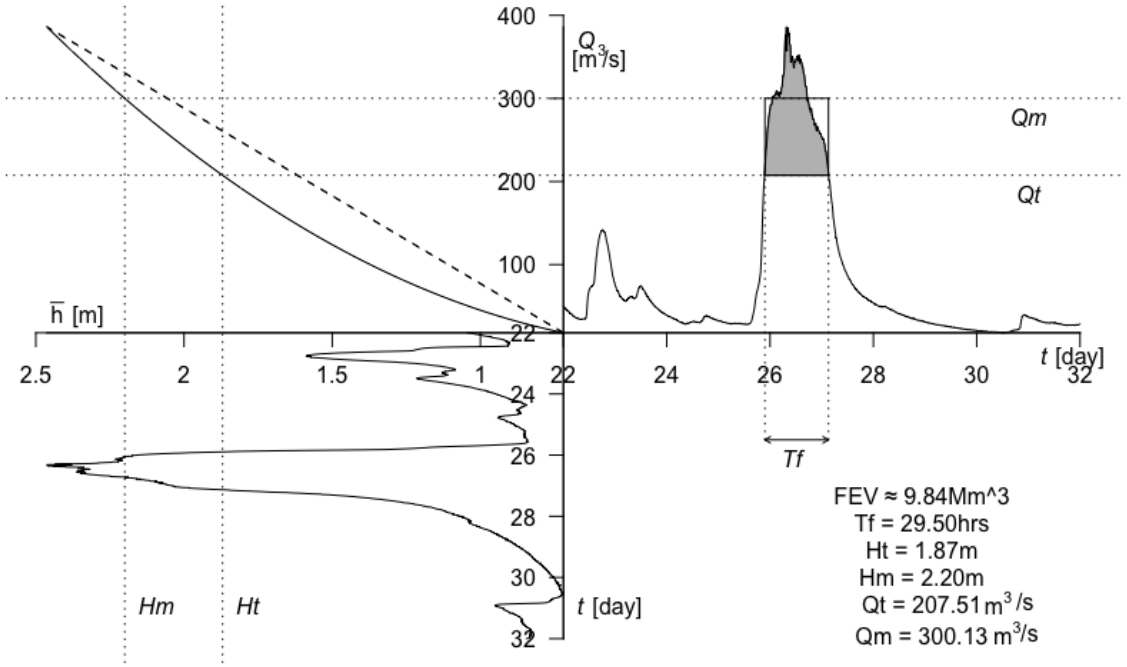

Figure 2: Quadrant plot depicting the Boxing Day 2015 Floods of the River Wharfe at Addingham, Yorkshire. The data used was compiled and requested for from the Environmental Agency.

4.3 Explanation of the quadrant plot

The quadrant plot of the Wharfe has the same set up as the previous graphs, however, we are still waiting on a response from the Environmental Agency regarding the values determining the rating curve. Instead, they provided data of their estimated flow rate based off a rating equation, as well as time and stage data. To create the rating curve, rather than using the rating equation, the Environment Agency's flow rate data was plotted against stage. Once the rating equation data has been received, it will be possible to evaluate Q_t and Q_m and T_f, and thus the F.E.V. for the river. Applying the rating equation to recreate the plot will be a method of ensuring the accuracy of the data provided by the Environmental Agency. Interestingly at Addingham, H_t is only 1.87m (estimated by the independent 'River Levels' website [7]), less than half of H_t at Armley on the River Aire, meaning its banks are a lot lower, and thus it would be reasonable to suggest, given the floods occurred over a similar time frame, that the F.E.V. of the Wharfe here would be much less than the F.E.V of the Aire, despite a similar degree of damage to infrastructure around both locations.

Still in edit phase so not fully structured as of yet.

[7] River Levels, River Wharfe at Addingham, https://riverlevels.uk/river-wharfe-nesfield-with-langbar-addingham.XBQkahP7R0s, 2018.