Anglian Water

12F. VALUATION OF THE IMPACT OF ROADWORKS AND FLOODING USING THE WELLBEING VALUATION METHOD

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Valuation of the impact of roadworks and flooding using the Wellbeing Valuation method

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1 Executive Summary

The aim of this study is to assess the impact of flooding and roadworks on the subjective wellbeing of Anglian Water customers. We place a monetary value on the wellbeing impacts estimated, to complement and validate estimates produced by other methods, such as stated preference, which are in use in the water industry already. The innovative nature of the work - in that it is the first time that the subjective wellbeing impacts of these water industry related incidents have been analysed in the UK - fits with the objectives of Ofwat's 2019 Price Review process (PR19) and provides a foundation for also applying the wellbeing valuation method to other types of water-related incident.

Anglian Water's overall valuation work for PR19 seeks to estimate the benefit of various services provided by the company, as part of a cost-benefit analysis (CBA) intended to guide its investment planning. In its recent Water 2020 consultation, Ofwat stated that it expects to 'see companies developing a robust, balanced and proportionate evidence base' and that 'while stated preference approaches will continue to play a role at PR19', the application of innovative techniques to the design and interpretation of customers' engagement with different aspects of Anglian Water's services is to be encouraged.

We use the Wellbeing Valuation (WV) approach, which calculates the value of each type of incident by estimating its impact on subjective wellbeing (SWB) for individuals who *experience* this incident in their life. Impact is then converted into a monetary amount, by estimating the equivalent amount of money they would be willing to pay to avoid each type of incident. This is an effective means of understanding the value of incidents, as it is likely that few people can correctly envisage the impact of these factors on their or other people's lives (an important aspect for considering the interpretation of other non-market valuation methods such as stated preference).

The analysis is conducted using the Annual Population Survey (APS) secure access dataset, a version of a large continuous household survey which runs from April 2011 to March 2016. It contains information on wellbeing (including a sample of Anglian Water's customers) and a wide range of socio-economic characteristics. We merged this data with information on flooding and roadworks incidents (including their type, postcode location, and dates) provided by Anglian Water. Using this data, we conducted multivariate ordinary least squares (OLS) regression analysis to estimate the impact on life satisfaction (the best-practice measure of overall quality of life) of:

- All types of flooding incident recorded by Anglian Water
- Internal water flooding
- Internal (domestic) sewer flooding
- External sewer flooding
- Roadworks

We classify survey respondents as potentially affected by a type of incident if there was such an incident within a specified distance of their postcode in a specified time period preceding their survey response. This group is then compared with a control group. As we control for a wide range of individual-level characteristics, the differences in SWB between the two groups provide a guide to the impact of the incidents. We make a number of adjustments to the analysis to aggregate the valuations accurately to a per incident level (defined as the value of one instance of an incident which can impact on multiple households) and a per property affected level. The main results are set out in Table 1 (a subset of the full results set out in the paper).

Table 1. Per incident and per affected property valuations (2017 price base, excluding compensation)

Incident type	All flooding	Water flooding (internal)	Internal sewer flooding (domestic)	External sewer flooding	Roadworks
Aggregated wellbeing value per incident	£390,552	£86,030	£263,814	£369,815	£31,735
Wellbeing value per incident per affected property	£24,930	£54,312	£166,549	£21,754	n/a

The **aggregated wellbeing value per incident** can be interpreted as an estimate of the total sum across households of the willingness to pay to avoid one incident based on the experiences of Anglian Water customers who reside in neighbourhoods that are affected by the incidents. The **wellbeing value per incident per property** can be interpreted as an average estimate of a typical properties' willingness to pay to avoid an incident of a given type. The key insights from the results provided in this research are:

1. **The wellbeing impact per incident for flooding is considerably higher than for roadworks**. In particular, roadworks represent a disturbance to people's quality of life which is more frequent in nature but has less impact per incident, whereas flooding is less frequent but has more impact when it does occur.
2. **Internal sewer flooding has a higher wellbeing impact per property than external sewer flooding.** An internal flood typically affects just one or a few households, but the wellbeing impact on those who are affected is strong. An external flood has a much lower wellbeing impact on each affected household, but the number of affected households is much greater meaning that the total incident value is larger.
3. **Internal water flooding has a lower wellbeing impact per property than internal sewer flooding**. While both sewer and water flooding may cause property damage and a disruption to water services provision, sewer flooding also brings about foul odour and negative health impacts, which corresponds to the higher monetary value of the welfare loss.

4. **Flooding and roadworks values per incident are higher in urban than in rural areas** – This is largely because incidents in urban areas tend to have a significantly higher number of households living nearby, due to greater population density, than is the case in rural areas.
5. **Repeated instances of a flooding incident do not impact as strongly on wellbeing as the first incident.** Whilst it is outside the scope of this study to explain why this may be the case, it may be fruitful in future work to explore the hypothesis that individuals adapt to the negative effects of repeated flooding, lessening the incremental impact of later incidents.

It is notable that adjusting the results for estimates of compensation for flooding paid out by Anglian Water in advance of subjective wellbeing responses does not affect the valuation results for any of the flooding types analysed. This is because compensation tends to be modest in relation to the overall impact of incidents.[1,2] The highest average compensation level is for water flooding at £920 per incident and makes up around 1% of the per incident wellbeing impact. Note that the figures we use only include compensation paid out by Anglian Water. This does not account for the possibility that households have received compensation from, for example, a private insurer.

We make further adjustments to the per incident values for internal and external sewer flooding to facilitate comparison with Anglian Water's stated preference values for PR19, which are estimated at a per property level. We find that the per property per incident impact of internal sewer flooding is £166,549, in comparison to a value of £101,000 (PR19 main stage study scaled linear value, Valuation Completion Report January 2018) in the stated preference work. Similarly, the wellbeing value per incident per property affected by external sewage flooding is £21,754, assuming that external flooding on average affects all of the properties that reside in a postcode. This compares with a stated preference value of £7,200 (scaled linear main stage study values taken from Valuation Completion Report, January 2018). The average wellbeing value per incident per property affected of water flooding is £54,312, based on the premise that it is internal, as the incidents were derived from insurance data (compared to a recommended PR19 scaled value of £32,869 taken from Valuation Completion Report, January 2018).

The stated preference water flooding values are derived by mapping the internal sewer flooding values to the wider measures for water flooding using weights (between sewer and water flooding) from the PR14 second stage flooding stated preference study. These weights were supported by customers in a round of PR19 relative preference focus groups. It is important to note that dividing the SWB value for internal sewer flooding by the SWB internal water flooding valuation produces an almost identical weight to those used in the stated preference work. This is supporting evidence for

1 As set out in Anglian Water's Code of Practice, Anglian Water have 20 working days to make a payment to the customer equivalent to their annual sewerage charges for internal sewer flooding incidents that it is responsible for. For external sewer flooding incidents, the customer has to claim compensation within 3 months of the incident and is entitled to claim a payment equal to 50% of their annual sewerage charges. Anglian Water do not have a specific policy in place for water flooding, but they consider claims when flooding has occurred due to their negligence.

2 For more information on Anglian Water's Code of Practice see: http://www.anglianwater.co.uk/_assets/media/AW_Codes_of_Practice_AW_Sept_2017.pdf

both the validity of the stated preference weights and the relative impacts of different incidents implied by the SWB analysis.

The differences between the results should be considered within the context that wellbeing valuation and stated preference rely on very different methods to infer value. Stated preference obtains a value from the respondent either directly or from a hypothetical choice response, meaning that it is prone to hypothetical bias, focusing bias and insensitivity to scale. Wellbeing valuation, in turn, estimates the subjective wellbeing impact of an incident based on a representative sample of those who have experienced it and those who have not. Further reasons for the differences between the Wellbeing Valuation and Stated preference results are elaborated on in the main body of the report.

To further assess the reliability of our results we also compare them with findings based on other measures of wellbeing. This analysis shows that exposure to flooding or roadworks is also associated with increased anxiety, and in the case of flooding, with reduced health (measured as self-reported general health) – results which corroborate the main findings derived by examining life satisfaction.

Whilst our analysis indicates that the results presented above provide a robust view of the impact of roadworks and flooding incidents, they are nonetheless a first application of wellbeing valuation methods to these categories of incident in the UK and are based on administrative data which was not collected specifically to cover the region serviced by Anglian Water. The analysis could be corroborated and expanded by collecting data on incidents and wellbeing directly from Anglian Water customers, for example through customer engagement work, and analysing this using subjective wellbeing methods. This could help overcome at source some of the statistical issues which instead have been adjusted for ex-post in this study, and would allow a wider variety of information to be collected, improving robustness and allowing for a fuller understanding of the mechanism by which wellbeing is impacted. Alternatively, for triangulation, the impact of incidents in regularly affected areas could be estimated using revealed preference (RP) methods. This would provide evidence of how people affected by these incidents have behaved in practice, e.g. in the price they have paid for housing which is free from flooding (hedonic pricing).

2 Context of the study

2.1 Research objectives and PR19 Context

The objective of this research is to assess the impact of flooding and roadworks incidents on the subjective wellbeing (SWB) of Anglian Water's customers and to value this impact in monetary terms to assist Anglian Water with its planning of investment and incident mitigation. We do this by using data on individuals' exposure to incidents and estimating the degree of statistical association between their exposure and SWB.

The study covers the following types of incident:

i) Water flooding
ii) Internal (domestic) sewer flooding
iii) External sewer flooding
iv) Roadworks

Ahead of its 2019 Price Review (PR19) Ofwat has set out that innovation is needed in the ways water companies engage with their customers and measure how customers value aspects of their business.[3] For instance, Ofwat has stated that "while stated preference willingness to pay approaches will continue to have an important role to play at PR19, it is also important for companies not to place sole or disproportionate reliance on such methods". This study is the first of its kind in the UK to test the impact of the flooding and roadworks incidents mentioned above on wellbeing using best-practice SWB research methods. We compare our results with stated preference estimates for triangulation. The use of SWB measures as a new form of customer engagement in the water industry is aligned with the increasingly important role of SWB in policy and business decision making, examples of which are as follows:

1. The establishment of the UK National Wellbeing Programme in 2010.[4]
2. The use of SWB metrics in Green Book and valuation studies in the UK.[5][6]
3. The centre stage role that SWB has taken in OECD wellbeing metrics and guidelines[7]
4. International trends elsewhere such as the uptake of the wellbeing valuation method by governments in Australia[8] and New Zealand[9].

2.2 Approaches to valuation

There is an extensive body of research in the water industry on methods for valuing the outcomes that water companies influence. This has grown out of the more general valuation literature in microeconomics, which has become the standard and best-practice approach to valuation (HM Treasury, 2011; OECD, 2013) At the heart of valuation of outcomes is the concept of two welfare measures developed by Hicks & Allen (1934):

- **Compensating surplus (CS)** is the amount of money, paid or received, that will leave the individual in their initial welfare position following a change from the status quo. For example, the CS for experiencing a flood (which reduces an individual's overall welfare) is

3 Ofwat (2016) Ofwat's customer engagement policy statement and expectations for PR19.
4 https://www.gov.uk/government/collections/national-wellbeing
5 https://www.gov.uk/government/publications/valuation-techniques-for-social-cost-benefit-analysis
6 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/372165/11-Quality_of_life--quality-of-life-assessment.pdf
7 http://www.oecd.org/statistics/oecd-guidelines-on-measuring-subjective-well-being-9789264191655-en.htm
8 http://arp.nsw.gov.au/sites/default/files/TPP17-03_NSW_Government_Guide_to_Cost-Benefit_Analysis_0.pdf
9 https://asvb.com.au/2017/08/01/new-zealand-treasury-signs-asvb/

the minimum amount of money that the individual is willing to accept to experience the flood.

- **Equivalent surplus (ES)** is the amount of money, to be paid or received, that will leave the individual in their subsequent welfare position in the absence of a change from the status quo. For example, the ES for experiencing a flooding incident is the maximum amount of money that an individual would be willing to pay to avoid experiencing a flooding incident.

The two main methods of valuing CS and ES in use in recent years in the water industry have been stated preference and revealed preference valuation.

2.2.1 Stated preference valuation

Stated preference (SP) techniques are survey-based methods which elicit monetary values of non-market goods and services by asking people what value they attach to specified changes in those goods and services. The two main techniques are: contingent valuation; and choice modelling, such as choice experiments.

- **Contingent valuation (CV)** asks respondents directly to report their maximum willingness to pay (WTP) for positive outcomes, or minimum willingness to accept (WTA) for negative outcomes, for the hypothetical policy change or change in the prevalence of events such as flooding or roadworks.

- **Choice modelling (CM)** is a multi-attribute preference elicitation technique used extensively in marketing, transport, and environmental valuation. Respondents are presented with a series of scenarios, each with differing levels of relevant attributes. Respondents are then asked to choose their most preferred scenario. If a monetary cost is included as one of the attributes, it is then possible to value the other attributes analysed by comparing the relative impact that cost and those attributes have on respondents' choice of scenarios.

The main advantage of stated preference methods is that they are extremely flexible, allowing a wide range of goods and services to be valued including future or planned changes. However, the approach also relies on individuals' assessment of scenarios which they may not have experienced in practice and can be subject to biases that reduce the accuracy of the values calculated.

2.2.2 Revealed preference valuation

Revealed preference methods estimate the value of non-market goods using data of how people behave in the face of real choices. This can be in the direct market or an indirect market. A direct market is where people are observed to make purchases directly in respect to the goods of interest. For example, the benefit of flooding reduction could be measured by how much people are prepared to spend on preventing the problem (the defence expenditure method). An indirect market approach is where value is revealed in wider market transactions, such as how much extra people are willing to pay for a house in an area which is not regularly affected by flooding (hedonic pricing).

2.3 Wellbeing valuation

Research in the relatively new area of Happiness Economics has led to the recent development of an approach to valuing CS and ES – two core measures of value - based on people's SWB rather than their preferences. The approach is referred to as **Wellbeing Valuation (WV)**. The method estimates value by inferring the impact of outcomes or goods on the SWB of individuals who actually experience these outcomes or good. Impact can then be converted into a monetary amount by estimating the equivalent amount of income they would be willing to pay to receive (avoid) the proposed positive (negative) change in policy.

We conduct our analysis using the Wellbeing Valuation (WV) approach. A key benefit of applying WV to water-related outcomes is that we are able to derive values without asking people directly or hypothetically how much they would be willing to pay (the SP method) and without relying on market data which may be limited in its availability (the RP method). Wellbeing values are based on how people actually experience an outcome (Fujiwara & Dolan, 2014). This is key in relation to flooding and roadworks where most people will not have experienced incidents directly and may struggle correctly to envisage the impact these factors might have on their lives. Another key benefit of applying WV to water related outcomes is that we can use extremely large samples of data on Anglian Water's customers (approximately 60,000 responses).

A potential challenge for the WV method is to find a suitable measure of SWB which can be captured accurately and without bias. With this in mind, SWB is usually measured as an 'evaluation' or as an 'experience'. It is said to be measured as an evaluation when people are asked to provide *holistic* assessments of their lives overall. Life satisfaction is an example of this approach, and is both the main measure used in social science (Diener, 2000) and WV research at present and the measure we use in this analysis. It has the benefit of providing a wide-ranging reflection of how people feel about their lives. Although SWB can also be measured as experience, whereby emotions are measured repeatedly through an individual's day to build-up a picture of their wellbeing, this approach often requires primary data collection and is therefore not the one taken in this study.

There is a variety of evidence to suggest that overall life satisfaction is a good measure of wellbeing. Whilst some studies have suggested that contextual factors such as the weather can adversely influence and bias life satisfaction responses, Eid & Diener, (2003); Fujita & Diener, (2005); Pavot & Diener, (1993); Pavot et al., (1991) and Schimmack & Oishi, (2005) find mood, question order and contextual effects to be limited. Further, bias due to mood is likely to average out in large representative samples. There is a range of evidence that demonstrates that there is a strong correlation between wellbeing ratings and a range of outcomes that we would intuitively relate to wellbeing such as emotions (smiling and frowning) and health (Kimball & Willis, 2006; Sales &

House, 1971), while life satisfaction has a high level of retest reliability (stability) (Krueger & Schkade, 2008). Overall, life satisfaction can be viewed as a reliable measure of wellbeing and as a consequence has been extensively used in the academic and government research literatures (Diener et al., 1999; Veenhoven, 2007). As a result, SWB is considered an appropriate way to estimate the relationship between flooding / roadworks incidents and wellbeing in large representative samples such as the Annual Population Survey (APS).

2.4 Previous studies conducted for Anglian Water

The interim valuations conducted for Anglian Water are briefly summarised in its PR19 Valuation Completion Report (January 2018), with the main stage study linear values included in the report compared to the wellbeing valuations in section 5.1. However, in this sub-section we present the key findings from the PR14 Valuation Completion report which relies, in large part, on the set of Anglian Water PR14 Willingness to Pay Studies including a main stage survey and a range of second stage WTP studies directly related to flooding.

This work estimated the societal value in monetary terms of the impact of changes in water, wastewater and environmental service levels. It found that sewer flooding inside properties has considerably greater impact than external flooding (the value of internal sewer flooding, £65,980, was found to be nearly ten times that of external flooding, £6,740 [Scaled PR14 values – PR14 Valuation Completion Report May 2013]). This is in line with the views of participants from qualitative research and engagement activities, who expressed the view that sewer flooding was a particularly serious and unpleasant incident which would impact on them greatly. However, despite the large magnitude for sewer flooding, with respect to customer service a majority of household (79%) and business (78%) respondents said they were happy with the current level of service for this type of incident, reflecting the low number of customers affected.

A second stage study (Second Stage Flooding Survey) focused on customers' views on the different types of flooding and possible solutions. This found that the value of internal sewer flooding (£65,980) was higher than that of internal water flooding (£22,098), even when the extent of the damage caused by each is identical ([Scaled PR14 values –PR14 Second Stage Flooding Survey: Final Report - May 2013]). This may be primarily because of the health risk that customers associate with sewer flooding. Specifically, the study suggested that sewer flooding in the home (including care homes) is viewed as the most serious incident by both household and business customers, followed by the sewer flooding of public organisations. This stage also revealed that the frequency of flooding (both sewer and water) was a key driver of willingness to pay by both types of customers, with those experiencing high frequency recording the highest values.

Previous valuations for Anglian Water of the traffic disruption and congestion caused by roadworks, as summarised in the PR14 Valuation Completion report, are based on a methodology published by

National Economic Research Associate (NERA, 1998). Their approach, as outlined in the Anglian Water Valuation Completion Report, is as follows:

1) Estimate the value of time – The Department for Transport calculated that the 'time cost' of an average vehicle per hour was £13.91 in 2010 prices.
2) Identify the type of road affected – e.g. major or minor road, and whether it is in a built-up area or not.
3) Identify the type of traffic disruption – e.g. lane narrowing, lane closure or diversions.
4) Calculate the changes in travel time – This is calculated by multiplying the extra minutes that each vehicle is disrupted by the number of vehicles.
5) Calculate total cost of the disruption – This is calculated by multiplying the delay time per vehicle by the number of vehicles and by the time cost per vehicle.
6) Sum all costs of the investment

The Anglian Water PR14 Valuation Completion Report sets out 12 valuations based on different types of roadworks incidents and levels of severity, the average of which was £9,277 per incident (May 2013).[10]

The remainder of the paper below is structured as follows: Section 3 describes the data and estimation models we used; Section 4 presents the main results; Section 5 our statistical robustness checks for the main results; and Section 6 our recommendations for further research.

3 Data and methodology

3.1 Data

This study draws on two main sources of data:

i) **The Annual Population Survey (APS) (5 waves, 2011 - 2016)** is a UK-wide continuous household survey. We use it mainly for information on respondents' wellbeing, which is used as the outcome variable in our analysis, and important social and socio-economic variables at personal and local levels, which are used as 'control variables'. We use a secured access version of the data, available in the ONS's Virtual Microdata Laboratory, as this provides the postcode of the respondent's home address, which is vital in ensuring we can identify who lives near to the studied incidents.

ii) **Data on flooding and roadworks incidents** provided by Anglian Water (incidents data). This includes information on the type of incident, the postcode in which the

[10] Simetrica calculations based on Table 10.12 of the Anglian Water PR14 Valuation Completion Report

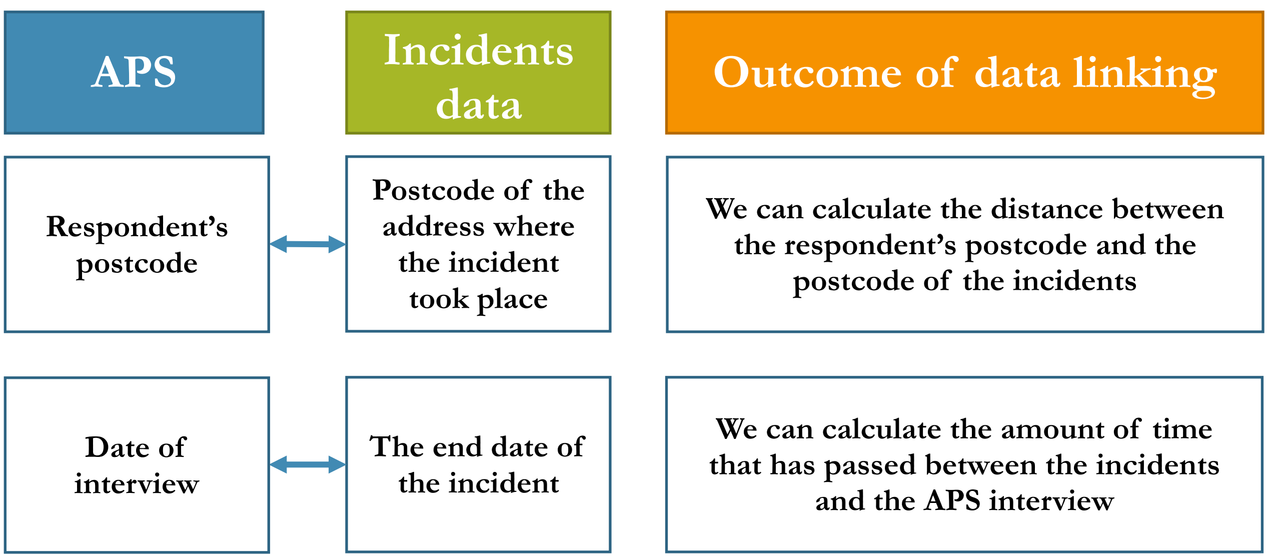
incident took place, and the dates over which it took place. It is based on Anglian Water's operational data and splits flooding/roadworks into four categories:

- Internal water flooding[11]
- Internal sewer flooding (domestic and non-domestic[12])
- External sewer flooding
- Roadworks

For the purposes of our analysis we also group the different flood categories (water, internal and external sewer) in an "All flooding" category.

We merge these two data sources based on: the postcode address of the respondent and the postcode of the incidents; and the date of the respondent's interview and the date when the incident ended (as some incidents last for more than one day). Figure 1 set outs the outcomes of merging these two datasets in terms of the implications for the analysis.

Figure 1. Linking the APS and incidents data



Note: The respondent's postcode is derived from the Grid reference positional quality indicator, provided by the ONS.

3.2 Methodology

It is crucial that in seeking to identify the impact of incidents on wellbeing we adjust, where possible, for the impact of wider factors correlated with the occurrence of incidents (but not caused by them) which also drive wellbeing. In econometric terms, this means to ensure that we adjust for any of the observable causes of endogeneity bias in our estimates of the impact of incidents on subjective wellbeing. For example, living in a densely populated urban area may make incidents more likely to occur (because of the increased density of pipework) and may also drive wellbeing in and of itself. It

[11] We assume the water flooding data is internal it is based on insurance payment records
[12] There is a very small number of internal non-domestic incidents in the data. As our results for this type of incident are statistically insignificant they are not reported in the study.

would not be appropriate in estimating the value of incidents to include the additional wellbeing impacts, if any, of living in an urban area per se. To help control for these and similar factors we employ a set of statistical models which seek to compare wellbeing for individuals *with and without* incidents who are otherwise similar and live in similar areas.

3.2.1 Econometric Specification

Our models seek to test the relationship between subjective wellbeing and proximity to flooding/roadworks incidents. In particular, we fit the econometric model below using multivariate ordinary least squares (OLS) regression analysis:

$$(1)\quad SWB_i = \alpha + \beta_1 \text{Incident}_\text{i} + \boldsymbol{X}_i\boldsymbol{\beta} + \varepsilon_i$$

where SWB_i denotes the subjective-wellbeing of individual i; $Incident_i$ is a dummy variable which takes the value of one if the respondent lives within a given distance of an incident and their interview in the APS took place within a given period of time since this incident (e.g. the respondent lives within 500m of an incident that took place no longer than six months previously) and zero otherwise; and $\boldsymbol{X}_i$ is a list of the control variables. The coefficient β_1 is the key coefficient for our analysis because if it is significant and negative it would imply that living near an area with flooding/roadworks incidents is associated with a reduction in an individual's wellbeing.

The models are run for a sample of respondents who reside only in Anglian Water's area of operations.[13]

3.2.2 Incident threshold selection

A key issue was to decide the time and distance thresholds within which individuals would be classified as having been affected by an incident. To do this we first ran econometric models for each combination of the following thresholds:

- Distance – Incident occurred within 50m, 250m, 500m, 1000m, 2000m of the individual's home postcode

- Time period[14] – Incident occurred at most 7, 31, 92, 183, 365, 730 days before the individual's APS interview

As set out in Table 2, we then chose the thresholds that best balanced the need for a material number of individuals to fall in each of the treated and non-treated groups (ensuring good sample

[13] A list of postcode areas was provided by Anglian Water.
[14] This time elapse is not the assumed duration of the incident, but rather the number of days between the incident and the interview.

size to minimise estimation error in the results) with the need for behaviourally plausible assumptions about the temporal and spatial range of the impact of incidents:

Table 2. Threshold selection for incident variables

Incident type	Distance threshold	Time period threshold
All flooding	<500m	<6 months (183 days)
Roadworks	<500m	<1 month (31 days)
Water flooding	<50m	<3 months (92 days)
Internal domestic sewer flooding	<50m	<6 months (183 days)
External sewer flooding	<500m	<6 months (183 days)

Note: We did not find any statistically significant results for any threshold for internal non-domestic sewer flooding.

It is important to note that these assumptions are made for analytical purposes (to ensure we can define whether or not each individual is affected by an incident) and are not expected to materially impact the size of the valuation results subsequently produced. This is because, as set out in detail in section 3.2.4, we then adjust our regression results to balance out the fact that not all individuals defined as affected may be impacted in practice (if impact does not stretch as far in time or place as is posited by the treatment threshold).

3.2.3 Description of variables used in the APS

The APS provides several SWB measures which are used as outcome variables in our analysis:

- **Life satisfaction** ("Overall how satisfied are you with your life these days?")
- **Happiness** ("Overall how happy did you feel yesterday?")
- **Anxiety** ("Overall how anxious did you feel yesterday?")
- **Sense of worthwhile** ("Overall, to what extent do you feel the things you do in your life are worthwhile?")

All responses are measured on a scale of 0-10[15] and form the four core wellbeing measures used in the UK's National Wellbeing Programme. In addition, the health analysis is conducted using the self-reported general health variable in the APS data set, measured on a five-point scale: 'very poor', 'poor', 'fair', 'good' and 'very good'. As noted in section 2.3, our primary measure is life satisfaction. This is because, being an evaluative measure, it offers a broad assessment of overall quality of life and has a large body of supporting evidence in terms of its validity and rigour. The other measures are used to corroborate and support the life satisfaction results.

The APS also provides a wide range of variables relating to survey respondents, including demographic characteristics, and socioeconomic factors. In our models we use these to control for a wide range of factors known to be associated with SWB and health. In particular we use the following, which are based on the control variables recommended in Fujiwara & Campbell (2011):

- Age
- Gender
- Marital status
- Ethnicity
- Educational status
- Employment status and earnings
- Religious affiliation
- Number of children
- Geographic region
- Urbanisation
- Wave of survey
- Month of interview
- Smoking
- Claiming benefits
- Survey Mode
- General Health (excluded in the regression model where health is an outcome variable)
- Local authority

3.2.4 Adjustments to the regression results – steps to generate a per incident valuation

The key objective of this research is to value the entire welfare loss associated with flooding and roadworks incidents. To translate the regression coefficient β_1 *for each type of incident into a per incident value we follow the approach set out in Table 3.*

[15] Where 0 is not at all satisfied, happy, anxious, or worthwhile and 10 is completely satisfied, happy, anxious, or worthwhile.

Table 3. Summary of the steps to calculate a per incident value

Step	Adjustment	Reason for adjustment
1	Divide β_1 by the average number of incidents of the specified type that occurred per affected individual in the time and distance threshold used for that type of incident	As the regressions use individual-level SWB data the coefficients give impact per person. Step one adjusts these to a per person *per incident* basis, by adjusting for the fact that the average affected respondent for each type of incident was assigned to more than one such incident.
2	Multiply the result of step one by the average household size in the Anglian Water region (2.39).	This ensures that impact is on a *per property rather than per person* per incident basis, a step towards eventual comparability with Anglian Water's Stated Preference results.
3	Multiply the result of step two by the time threshold used for the incident but expressed in years, e.g. 1/2 for all flooding (6 months)	The monetary valuation method provides an annual value, and therefore unless an incident's time threshold lasts exactly a year, we need to adjust the associated life satisfaction impact with respect to its time threshold before monetising (see step 4).
4	Monetise the result of step three based on the impact of income on wellbeing	This converts impact to a monetary basis. The resulting value is on a per incident per *potentially affected* household basis *for the average household in the treatment threshold* (note that households could be impacted in practice or be too far away in the area to have been affected directly).
5	Multiply the valuation by the average number of households within the distance threshold (calculation of this number is described in section 3.2.4.2)	This adds up the effect for each potentially affected household, accounting for the fact that the initial valuation is an average for all households in the posited area whether these are affected in practice or too far away to have been impacted. The resulting value is therefore on a per incident basis.
6	Add the average compensation paid per incident to the per incident wellbeing value (the method for calculating the average compensation per incident is described in section 3.2.4.3)	This ensures that the valuations account for compensation paid to respondents by Anglian Water, which would otherwise result in downward bias to the estimates (as life satisfaction values in APS are de facto net of the satisfaction respondents may have gained from compensation). Note that private insurance payments are not added to the valuations although they theoretically should be included. This means that the valuations are net of any private insurance payments received as a result of the incidents within the time threshold.

3.2.4.1 Further details on step 4: Monetisation and duration adjustments

The monetary value of the wellbeing impact of a type of incident can be estimated from the relative impact on wellbeing of income and that type of incident. This relativity, referred to as the marginal rate of substitution (MRS) between the two factors, is calculated as follows:

$$MRS = \frac{\beta_Q}{\beta_M} \quad (2)$$

where β_Q is the incident coefficient from the regression, adjusted as set out in steps 1-3 above, and β_M (the impact of income on SWB) comes from Fujiwara and Dolan (2016), which uses lottery wins as exogenous variation in income to estimate the causal effect of income on life satisfaction. As the impact of income is calculated using a non-linear specification (the log of income), the valuation of changes in life satisfaction varies with households' level of income. Households in the Anglian Water region earn approximately the UK median income and so we use a median income estimate of £30,000 per year. With these inputs we estimated the **equivalent surplus** of having an incident[16], which gives the total **willingness to pay (WTP) to avoid** an incident for households affected by the incidents within the treatment area.

3.2.4.2 Further details on step 5: Aggregating across households

We estimated the average number of households over which the total wellbeing effect of the incident is spread out (H) by summing all households within the relevant distance threshold of a random sample of 200 such incidents[17] (counting a given household twice if it appears within the orbit of two different incidents) and dividing by the number of incidents analysed (200). We calculated (H) separately for each incident type - roadworks, internal domestic sewer flooding, external sewer flooding, and water flooding - based on the distance threshold that was used for the treatment variable for the incident in question.

We then aggregated the valuation result for each type of incident by multiplying the per household per incident wellbeing value from step four by the average number of households affected by an incident, calculated as set out above. This estimates a value per incident.

Step five also adjusts automatically for downward bias in the wellbeing valuations per household per incident which arises at the regression stage. The bias occurs because not every household within the distance threshold chosen for the type of incident may be affected by an incident of this type in practice, e.g. some may live far enough away within the threshold that impact is negligible.[18] As a result of the bias, the raw estimated impact will be an average of the true impact (measured from those who *were* affected) and zero (measured from those who were *not*). This is most pertinent for internal domestic incidents, which occur at a specific address but (as the Annual Population Survey is only made available at postcode level) are deemed in the analysis to have affected every household within the given radius. However, it also applies to the other types of incident, which once again may not affect all households within the radius assumed.

In multiplying the value per household per incident by ($\boldsymbol{H}$), step five deals with this bias. Suppose for example that the total wellbeing impact across individuals actually affected by an incident is ($\boldsymbol{W}$).

[16] We can also express the calculations in terms of compensating surplus, which would be the willingness to accept the potential experience of an incident.
[17] We use 2011 Census Data on population at postcode level to do this.
[18] Note that the impact of an internal flood on neighbours may affect the wellbeing of the respondent if there is altruism.

As we have defined $(\boldsymbol{H})$ individuals as being affected by the incident, with $(\boldsymbol{W})$ distributed over this group, mean wellbeing in the group is $(\boldsymbol{W}/\boldsymbol{H})$ higher than mean wellbeing for those outside. Our regression coefficient will therefore capture a wellbeing impact of $(\boldsymbol{W}/\boldsymbol{H})$ on average. This holds true regardless of the number of individuals actually affected, so long as they all fall within the distance threshold chosen. Multiplying the per household per incident value by $(\boldsymbol{H})$ therefore fully adjusts for the possibility that not all households in the assumed impact areas are affected in practice.

It is likely that households can be affected by incidents in the following ways:

- **Direct impacts** – at the respondent's address (e.g. sewer flooding within the property; or roadworks on a street which the respondent uses).
- **Indirect impacts** – these include the discomfort caused by an incident affecting the outdoor areas – limited access to streets, gardens, passageways etc., as well as spillover impacts of incidents on neighbours (e.g. helping your next-door neighbour who has had a flood), or on the local community (e.g. concerns about changing house prices due to a local flooding incident or about community cohesion during a flood).

3.2.4.3 Further details on Step 6: Adding average compensation to per incident value

We calculate **average compensation payments made by Anglian Water**[19][20][21] in the following way:

(3) $$Average\ compensation = \frac{T*C}{N}$$

where (T) is the total amount of compensation paid in respect of incidents of a certain type in a given financial year; (C) is the estimated share of households who had received their compensation before they were interviewed for the APS[22]; and (N) is the number of incidents that occurred in the time period corresponding to the compensation.

We add average compensation to the per incident wellbeing value for:

i) External sewer flooding

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[19] As set out in Anglian Water's Code of Practice, Anglian Water have 20 working days to make a payment to the customer equivalent to their annual sewerage charges for internal sewer flooding incidents that it is responsible for. For external sewer flooding incidents, the customer is entitled to claim compensation within 3 months of the incident and can claim a payment equal to 50% of their annual sewerage charges. Anglian Water do not have a specific policy in place for water flooding, but they consider claims when flooding has occurred due to their negligence.

[20] This is only compensation provided by Anglian Water and doesn't include any insurance compensation received.

[21] For more information on Anglian Water's Code of Practice see: http://www.anglianwater.co.uk/_assets/media/AW_Codes_of_Practice_AW_Sept_2017.pdf

[22] For internal sewer flooding we assume 90% receive compensation within 10 working days of incident and 10% claim within 1.5 months on average and get compensation 10 working days later. For external sewer flooding we assume that 100% claim within 1.5 months on average and get compensation within 20 working days. For water flooding, we directly calculate the amount of compensation received within three months of an incident.

ii) Internal domestic sewer flooding

iii) Water flooding (assumed to be internal)

3.2.4.4 Obtaining values per incident per property affected to aid comparison with stated preference valuations

We make further adjustments to the per incident internal domestic sewer flooding value to aid comparison with Anglian Water's stated preference results, which are estimated at the level of per property directly affected. To do this, we divide the wellbeing value of an incident of each type by the estimated average number of properties affected by an incident of that type. Below we set out how we estimate the number of properties affected for each type of incident. It is worth noting that, as it is based on the overall per incident valuation, the valuation per property also includes indirect impacts on the local area. This affects the extent to which these values can be compared to Stated Preference values, which are based on survey respondent's impression of the scale of impact, as well as any altruistic concerns for properties which are directly affected.

For internal sewage flooding, the estimate of the number of properties affected is directly calculable from data provided by Anglian Water. It is equal to the ratio of the number of incidents in a given financial year and the number of properties affected in that year.

For external sewage flooding it is trickier to estimate the number of properties affected. By definition, an external flood spills outside the premises where it occurred, and may spread onto the street, public motorways, agricultural lands, neighbouring properties, gardens or public green spaces. In such events, all members of the local community will be affected, and perhaps some passers-by as well. Their number cannot be easily extracted from the data, which only contains the households that reported the incident, but not those that experienced collateral disutility. On the other hand, the number of households within the regression distance threshold, described in section 3.2.4.2, is an overstatement, as it might contain many people that live too far away to experience any effect. Based on these considerations, we assume that an average external flood will affect approximately all households living within a postcode. We thus used the average number of households in a postcode in the Anglian Water region as a best estimate for the number of properties affected by an external sewer flood.

For all flooding, the number of properties affected is a weighted average of the values for internal and external flooding, with the weight factors equal to the share of the respective incident type in the flooding data. Water flooding was treated as internal, based on feedback from Anglian Water and because it is based on insurance data. In the absence of similar data available for water flooding, we assume that the average number of properties affected by a water flood is equal to that of an internal sewage flood.

3.2.5 Other model specifications

3.2.5.1 Disaggregated analysis

We also ran the model described in equation (1) on subsample groups. The aim of this analysis was to understand whether incidents have differing impacts for different demographic subgroups in Anglian Water's customer base and to identify the specific aspects of incidents which have the greatest impact on wellbeing. We split the model using the following subgroups:

- Urban/rural customers
- Types of traffic management (e.g. crosswalk incursion, two-way signal)

3.2.5.2 Quadratic model

We also looked at the value of repeated instances of flooding/roadworks using the following quadratic model:

$$(4)\quad SWB_i = \alpha + \beta_1 \text{Incident}_{\text{i}} + \beta_2 \text{Incident}_{\text{i}}^2 + \boldsymbol{X}_i \boldsymbol{\beta} + \varepsilon_i$$

Where $\text{Incident}_{\text{i}}^2$ is the squared term of the number of incidents that the respondent is affected by in a given time threshold. This model allowed us to test for non-linearity in the impact of incidents within a given time threshold, for example diminishing marginal impact whereby the impact of the second and subsequent incident(s) has a smaller impact on SWB than the first (equivalent to a negative and statistically significant β_1 and a positive and statistically significant β_2).

4 Results and interpretation

4.1 Descriptive statistics

Table 4Table 4 presents descriptive statistics for the analysis. The first row shows that sample size for the regressions was 64,526 APS respondents (inclusive of those deemed to be potentially affected and those deemed not), indicating that the analysis is based on a very large sample of respondents who live in areas served by Anglian Water.

After the combined flooding incident type, roadworks have the highest number of respondents potentially affected by a specific incident (26,800 according to our optimal threshold definition). On the other hand, the incident type with the lowest number of affected respondents within the optimal threshold, is internal sewer flooding with 85 observations. This is in line with the relatively low total number of internal sewer flooding incidents (3,131) compared to roadworks incidents (264,061).

Table 4. Descriptive statistics – sample size by incident type

		All flooding	Water flooding	Internal sewer flooding (domestic)	External sewer flooding	Roadworks
1	Sample size – in regression	64,526	64,526	64,526	64,526	64,526
2	Sample size – number of respondents potentially affected by incidents (according to optimal threshold definitions)	27,491	747	85	24,646	26,800
3	Total number of incidents within raw data (after removing duplicates) [23]	56,291	5,063	3,131	47,208	264,061
4	Sample size in APS April 2011-March 2016 (entire UK)	822,625				

4.2 Main results

Table 5 shows the wellbeing value of each incident type per incident (row 11) and per property affected (row 13). These values account for compensation. The final per incident values can be interpreted as an estimate of the sum of willingness to pay to avoid one incident based on the experiences of Anglian Water's customers who are in the neighbourhoods affected by it. From this, we distinguish the following patterns:

The wellbeing impact *per incident* of each type of flooding is considerably higher than for roadworks. Whilst roadworks are more frequent in nature than this type of incident as set out above (264,061 incidents in the data versus 56,291 for All flooding), they have an average wellbeing value per incident that is more than ten times lower than All flooding.

Internal sewer flooding has a higher wellbeing impact *per property affected* than external sewer flooding. This reflects that, by definition, internal floods typically affect fewer households per incident. Although the total welfare loss from an external sewage flood is greater, the fact that this welfare loss is spread over more properties makes the average per property value lower. In comparison, internal floods have a much higher wellbeing impact on each household affected, but the number of such households is much smaller.

Internal water flooding has a lower wellbeing impact per property affected than internal sewer flooding. Given the latest feedback and the fact that they originate from data on insurance

[23] Duplicate incidents were defined as incidents of the same type, which happened in the same postcode, at the same date and time.

claimants, water flooding incidents were classified as internal. Their wellbeing association and the resulting wellbeing values are about three times smaller than those of internal sewer incidents, both in per incident and per property affected terms. While both sewage and water flooding may cause property damage and a disruption to water services provision, sewage flooding also brings about foul odour and negative health impacts, which corresponds to the higher monetary value of the welfare loss.

Table 5. Wellbeing values by incident type

	Incident type	**All flooding**	**Water flooding(internal)**	**Internal sewer flooding (domestic)**	**External sewer flooding**	**Roadworks**
1	Distance and time threshold	500m, 6 months	50m, 3 months	50m, 6 months	500m, 6 months	500m, 1 month
2	Regression coefficient	-0.044	-0.273	-0.508	-0.041	-0.026
3	Average number of incidents per affected respondent	2.01	1.03	1.10	1.89	2.30
4	Per incident coefficient (2/3)	-0.022	-0.265	-0.460	-0.022	-0.011
5	Average household size in the region serviced by Anglian Water	2.39	2.39	2.39	2.39	2.39
6	Per incident per household potentially affected coefficient (4*5)	-0.052	-0.634	-1.100	-0.052	-0.027
7	Per incident per household potentially affected wellbeing value (adjusted for duration of impact)	£450	£2,648	£8,195	£448	£40
8	Average number of households potentially affected	868	32	32	826	795
9	Aggregated wellbeing value of incident (7*8)	£390,552	£85,110	£263,365	£369,811	£31,735
10	Average compensation per incident	N/A	£920	£449	£4	N/A
11	Compensation + wellbeing valuation of an incident (9+10)	£390,552	£86,030	£263,814	£369,815	£31,735
12	Average number of properties affected by an incident	15.666	1.584	1.584	17	N/A
13	**Final wellbeing value per property affected by an incident**	**£24,930**	**£54,312**	**£166,549**	**£21,754**	**N/A**

Note: Calculations may not add up precisely due to rounding. All regressions coefficients in row 2 are found to be statistically significant. Full regression models with all controls are available upon request.

4.2.1 Compensation values for water and internal/external sewer flooding

As set out in Section 3.2.4.3, for each type of flooding we add an average level of compensation paid by Anglian Water per incident to the aggregated wellbeing value per incident. The exception is for 'All flooding', where usable data is not available. Equally, compensation is not paid for roadworks.

Overall, we find that **compensation has a negligible effect on the total wellbeing values of the types of flooding analysed** - We find that the average compensation values are relatively small (compensation for internal sewer flooding makes up less than 0.2% of the resulting per incident wellbeing value, whereas for water flooding it is around 1% and for external sewage flooding it is minute).

4.3 Disaggregated analysis

Our estimates of the wellbeing values for the different subgroups outlined in section 3.2.5.1 show some variation by subgroup. These findings are set out in Table 9-11 in the Annex, of which the key points are covered below.

4.3.1 Urban/rural

Table 9 sets out the results of analysis where we partition the sample to understand the impact of flooding/roadworks on residents living in rural versus urban areas. We found that:

The average flooding incident has a greater overall impact in urban areas than rural. This is driven largely by the greater number of urban households lying within 500m of an incident (1233) than rural households (429). Wellbeing values per property affected by flooding are lower in urban areas.

The average roadwork incident has a greater impact in urban areas. This is due both to a higher value per household affected and a higher number of people affected in urban areas.

4.3.2 Traffic management

Table 10 shows the valuations per incident for specific types of traffic management. We find that:

The 'Stop/Go Boards' system has the greatest impact per incident on wellbeing, although this could be driven by outliers in the data. However, it is possible this and the other high values in Table 10 may be driven by outliers (very large values) in the data expressed by low subsamples of respondents affected by these types of incidents. Results for these types of traffic management should therefore be interpreted with caution.

4.3.3 Number of flooding/roadworks incidents

Table 11 shows the differences in wellbeing value according to the number of flooding incidents.

The second flooding incident has a lower impact on wellbeing than the first – In contrast to stated preference findings, a second instance of a flooding incident (valued at approximately £285,000 per incident) does not have as strong an impact on wellbeing value as the first instance (valued at approximately £487,000 per incident). It is possible that those who experience flooding repeatedly are more prepared to deal with, or adapt to, the negative impacts of the incident and as a result value it less highly on repeat occasions. Note that this finding is consistent with the theory of hedonic adaptation, which posits that there is a psychological process which attenuates the impact of a favourable or unfavourable change in circumstances (Frederick & Loewenstein, 1999).

4.3.4 Further disaggregated results (statistically non-significant)

We conducted further disaggregated analysis which did **not** produce statistically significant or reliable results:

- **Timing of incident** –We did not find a consistent pattern between the timing of a flood and its impact on the wellbeing values.
- **Roadworks by size (length + width)** – The values for this analysis were of similar magnitude to the baseline roadworks incident model, which indicates that the size of roadworks alone does not materially influence SWB.
- **Roadworks by duration thresholds** – The results were statistically insignificant.
- **Size of sewer flooding spill** – The results were statistically insignificant for some of the spill sizes.

5 Assessment of results and triangulation

5.1 Comparison with alternative valuations

The recently published preliminary PR19 values provide the outcomes of a new stated preference study. The WTP values are provided in scaled and unscaled, as well as gains / losses versions. Table 6 sets these values alongside the values obtained in the present WV study. According to the PR19 Valuation Completion report, scaling is designed to account for so-called "package effects," i.e. that the stated preference survey asked each respondent to separately value incremental changes in service levels aimed at preventing different types of incidents, whereby the willingness to pay to prevent all types of incidents is expected to be less than the sum of the WTP to prevent each type of incident individually, as individuals are constrained by a budget.

Scaled or unscaled stated preference values

We recommend that the wellbeing results are most closely aligned with the scaled SP values. This is because an individual's life satisfaction level, used in the Subjective Wellbeing (SWB) analysis, by its nature captures wellbeing in the full context of survey respondents' life and other circumstances, including the possibility of other incidents or incident types that may have occurred in their area, to the extent that they affect the respondent. The wellbeing impact of incidents therefore also captures impact contextualised in this way.

Furthermore, as our wellbeing values are designed to be interpreted as a willingness to pay to avoid an incident, they are constructed in such a way that the valuations are constrained at a maximum to the sample average household income (£30,000); this reflects the assumption made that an individual cannot be thought of as willing to pay more annually than their full annual income. Our conclusion is that the wellbeing monetary values are therefore more comparable to the scaled SP values.

Gain or loss-based stated preference values

It is common in stated preference to find differences between gain and loss estimates. For comparison purposes, the Wellbeing Valuation (WV) estimates are most comparable to the weighted average of the scaled PR19 gains/losses (or scaled PR19 linear values). This is because the wellbeing values are an average of gains (removal of the experience of flooding) and losses (occurrence of the experience of flooding), weighted by the proportion of the sampled people that experienced or did not experience flooding respectively. The Valuation Completion Report, undertaken for Anglian Water as part of the Societal Valuation Programme, makes further recommendations for how the Wellbeing Valuation (WV) estimates are applied alongside other primary valuation evidence for PR19 business planning purposes.

Further considerations

There are a number of potential reasons for why the stated preference results and our wellbeing results may differ:

- As mentioned in Section 2.3, the WV approach ensures that we are capturing the impact of an incident in terms of how people have experienced it in real-life, as opposed to asking them about a hypothetical scenario which they may not have experienced and thus may not value entirely accurately.
- WV only captures the impact of an incident at the fixed point in time when the respondent answered the wellbeing survey. Although different respondents affected by flooding will have different amounts of time elapsed before they were surveyed, WV cannot value future

changes in SWB that arise from experiencing the incident, unless these are anticipated at the time of the survey and the anticipation has already impacted wellbeing in full.

- The WV approach does not include purely altruistic behaviour (i.e. concern for impact on a complete stranger), although it is likely to pick up traces of impacts on the wellbeing of individuals who were affected by an incident affecting others in their local neighbourhood, be that out of concern for neighbours, concern for the impact on property prices, or other potential reasons. With the data available there is no consistent way of isolating this component.

It is also notable that the stated preference values represent willingness to pay per property for a given change in the risk of flooding, whilst the wellbeing values capture the average welfare impact of a flooding event that has already occurred, per property affected. This might deliver wellbeing valuations that are higher than SP estimates, which other things equal might justify scaling the wellbeing valuations from 100% likelihood to the relevant increase in likelihood posited in collecting the SP data, the latter adjusted if necessary for summation and discounting over time.

The stated preference water flooding values are derived by mapping the internal sewer flooding values to the wider measures for water flooding using weights (between sewer and water flooding) from the PR14 second stage flooding stated preference study. These weights were supported by customers in a round of PR19 relative preference focus groups. It is important to note that dividing the SWB value for internal sewer flooding by the SWB internal water flooding valuation produces an almost identical weight to those used in the stated preference work. This is supporting evidence for both the validity of the stated preference weights and the relative impacts of different incidents implied by the SWB analysis.

Finally, we also note that the Roadworks wellbeing valuation is approximately three times greater than the PR14 valuation. This is likely due to the wellbeing valuation approach being able to pick up aspects of the full range of community impacts, whilst the PR14 method focused solely on travel time impacts.

Table 6. Comparison of wellbeing valuation and stated preferences values

	Water flooding	Internal sewer flooding (domestic)	External sewer flooding (domestic)	Roadworks
PR19 Wellbeing valuation	£54,312	£166,587	£21,754	£31,735
Other PR19 valuations (Flooding values based on stated preferences, scaled, gains / losses midpoint)[24]	£32,869	£101,500	£7,200	n/a

[24] PR19 main stage study linear values (Valuation Completion Report, January 2018)

PR14 (Flooding values based on stated preferences, scaled, gains; Roadworks values based on the Value of time approach – in 2018 prices)	£22,098	£65,980	£6,740	£9,973[25]

5.2 Sensitivity analysis

To acknowledge and quantify statistical uncertainty in the results presented in Table 5, we produced confidence intervals. Table 7 displays the upper and lower bound confidence interval values (at the 90% level) for the aggregated wellbeing value for each type of incident, based on uncertainty about the following estimates:

- the per incident per household wellbeing value (the uncertainty coming ultimately from uncertainty in the underlying regression coefficients)
- the number of households affected by each incident

Table 7. Confidence intervals, by incident type

		All flooding	Water flooding	Internal sewer flooding (domestic)	External sewer flooding (domestic)	Roadworks
1	Per incident per household potentially affected wellbeing value	£450	£458	£8,195	£448	£40
2	90% CI – lower bound	£204	£105	£2,639	£179	£0.50
3	90% CI – upper bound	£694	£808	£12,623	£714	£79
4	Number of households affected by incident	868	889	32	826	795
5	Number of households affected – 90% CI low	794	794	29	754	721
6	Number of households affected – 90% CI high	942	985	35	898	869
7	**Aggregated wellbeing value of incident**	**£390,552**	**£407,654**	**£263,365**	**£369,811**	**£31,735**
8	**Aggregated wellbeing value per incident – 90% CI low***	**£162,028**	**£83,228**	**£77,039**	**£134,894**	**£358**

[25] Adjusted for inflation using GDP deflator data provided by the Department for Transport WEBTAG model

9	**Aggregated wellbeing value per incident – 90% CI high***	**£653,474**	**£795,544**	**£442,802**	**£641,225**	**£68,887**

Note: * These valuations take into account the sampling errors for both the estimation of the main regression coefficients and the average number of households affected by each type of incident.

5.3 Wider wellbeing measures

To corroborate the main results based on life satisfaction we also analysed other measures of wellbeing, hypothesising that incidents would be associated with greater levels of anxiety and lower level of health.

Table 8 below sets out the estimated relationship between each of these outcomes (columns 2 and 3) and being affected by a flooding or roadworks incident within the specified distance and time thresholds. The life satisfaction coefficients from the main analysis (column 1) are included for comparison.

We found that the **direction** of the coefficients for health and anxiety are in line with the coefficients for life satisfaction for flooding. This corroborates the hypothesis that these incidents are associated with lower levels of wellbeing. For roadworks, the direction of the anxiety result is in line with the life satisfaction results, in that people in areas potentially affected by roadworks report higher levels of anxiety. The results for health for this type of incident are not statistically significant.

We also found that where the results for the alternative wellbeing measures were statistically significant, the **magnitude** of these impacts was broadly similar to the impact on life satisfaction. This offers corroborating evidence for the magnitude of the life satisfaction impacts.

Table 8. Further wellbeing measures for triangulation, by incident type

	1	2	3
Regression coefficients	**Life satisfaction (0-10)**	**Health (adjusted to a 0-10 scale)[26]**	**Anxiety (0-10)**
All flooding within 500m in 6 months	-0.044***	-0.035***	0.062***
Roadworks within 500m in 1 month	-0.026***	(N/S)	0.054**

[26] The initial health coefficient (-0.016) is on a 1-5 scale. To convert this to a 0-10 scale, we multiply the coefficient by 11 and divide by 5 to get -0.035.

Note: The wellbeing measures 'Happiness' and 'Sense of worthwhile' are not included as they were not found to be statistically significant. The "Health" wellbeing measure for roadworks incidents is also not included due to lack of statistical significance.

5.4 Caveats

A key consideration in Wellbeing Valuation is to ensure reliable estimation of the statistical models that underlie the monetary calculations, in this case reliable estimates of the impact of flooding/roadworks and income on wellbeing.

This study drew on best-practice estimates of the impact of income on wellbeing from an Instrumental Variable model based on lottery wins data (Fujiwara and Dolan, 2016). As experimental data[27] was not available to us on incidents, we estimated the impact of these using multivariate regression. Although the main determinants of SWB were controlled for in this analysis, as is in line with key wellbeing studies, it remains the case that some confounding factors may be at play which are not observed in the data. **These factors ensure that we cannot ultimately state that incidents have a causal effect on wellbeing** (as the relationship could instead be driven in part or in full by these unobserved factors). If, for example, incidents are more likely to occur in areas with bad weather, where wellbeing may be lower anyway for that reason, our estimates of the value of incidents may be too high. This caveat reflects a limitation which is inherent to almost all forms of policy evaluation, as very few studies have experimental data.

In addition, whilst in aggregating values over the average number of households within the distance threshold used for each incident we seek to cancel any attenuation bias, this adjustment may not be fully successful in practice. Aggregation adjusts for the possibility that some households within the distance threshold are *not* affected, despite being coded in the analysis as affected[28]. However, it does not account for the possibility that some households affected by an incident may live beyond the immediate locality (i.e. outside the geographical radii we used in the analysis). This might be particularly relevant for traffic measures, where some households may be affected by virtue of commuting through impacted areas rather than living there. Equally, the distance thresholds used for internal incidents (50m) and external incidents (500m) do appear intuitively to be wide enough, suggesting that this factor may not impact the results materially.

There is also potential measurement error arising from the fact that distances are calculated from the centre of the respondent's postcode rather than from the exact location of their house (as only the postcode was available). Similarly, some incidents did not have a postcode or other geographical identifier provided[29], as a result of which, some respondents in the APS may be incorrectly coded as

[27] One of the best methods to estimate a causal effect is a Randomised Control Trial (RCT). In our case, this would mean randomly assigning floods / roadworks to selected streets/properties, without regard to their characteristics. Such an approach is clearly infeasible.
[28] E.g. because they live locally but on a different street from the incident
[29] A total of 0.02% of roadworks incidents, 33% of water flooding incidents, and 10% of sewer flooding incidents did not have a postcode in the raw data from October 2010 to April 2016 (the years of the data which map to the APS data and the time thresholds used).

unaffected by incidents despite having been affected in reality. Both of these factors could, in principle, bias the estimated valuations downwards.

Another potential caveat to the analysis is that the flooding values reported above are net of any form of third-party insurance payments that are unrecorded by Anglian Water but may have been received by individuals before their responses to the APS. This means that the full wellbeing impact of flooding incidents may be larger than the results provided here.

Finally, the sample size for the number of households affected by internal domestic sewer flooding is low at n=85. Whilst the results for this type of incident are statistically significant despite this small sample, they should be interpreted with this caveat in mind. The potential problems with this are that the results may be driven by outliers in the data, and that there is potentially low external validity in generalising these results to the population of households affected by internal domestic sewer flooding incidents.

6 Conclusion and future research

To the best of our knowledge, this is the first study to measure the impact on subjective wellbeing of water-industry-related flooding or roadworks incidents in the UK.

The work produces a coherent narrative and set of overall results regarding the detrimental impact of flooding and roadworks on people's wellbeing. In particular, all of the analysis indicates that exposure to a flooding/roadworks incident is associated with reductions in wellbeing (measured as life satisfaction and anxiety) and, in the case of flooding in particular, health (measured as self-reported general health). Furthermore, we find that flooding and roadworks incidents have a greater impact in urban areas, in part because of the greater number of households living there.

The study also estimated values related to impacts on wellbeing through the wellbeing valuation method. We compared valuation estimates for roadworks and flooding and between different types of flooding, revealing differences which can be rationalised in light of the data, for example, the finding that internal sewer flooding has greater impact and cost per household than external sewer flooding but less impact per incident overall than externally (as internal incidents tend to affect fewer households).

Equally, comparison with the PR19 WTP report indicates that the wellbeing values are somewhat higher than the scaled PR19 stated preferences values, but lower than the unscaled ones. We conclude that the wellbeing monetary values are more comparable to the scaled SP values. Differences between WV and SP values are due to distinctions in the two techniques. In particular, the SP values represent a given change in the risk of flooding, while the wellbeing values represent the average welfare impact of a flooding incident that has already occurred.

However, we recommend that further research may be fruitful in the following areas to confirm and extend the key findings as well as generating valid and best-practice insights in other areas. We will set out this further research in a separate forthcoming note to be provided to Anglian Water.

7 Annex

[Full regression outputs can be made available upon request]

Table 9. Disaggregated analysis – Wellbeing values by urban and rural residents

Incident	Whole sample (aggregated wellbeing value of incident)	Urban (aggregated wellbeing value of incident)	Rural (aggregated wellbeing value of incident)
Flooding within 500m in 6 months	£390,552	£477,934	£253,929
Roadworks within 500m in 1 month	£31,735	£61,696	(N/S)

Table 10. Disaggregated analysis – Wellbeing values by type of traffic management

Roadworks within 500m in last 1 month – by type of traffic management	Per incident, per household wellbeing value	Aggregated wellbeing value of incident	Affected respondents (% of sample)
Give & Take	£329.89	£262,315	2.17%
Stop/Go Boards	£516.93	£411,035	0.66%
Two-Way Signal	£225.18	£179,051	3.30%
Some Crosswalk Incursion	£78.64	£62,533	12.83%

Table 11. Disaggregated analysis – Wellbeing values by number of incidents

	Flooding (per incident per household wellbeing value)	Flooding (Aggregated wellbeing value of incident)	Roadworks (per incident per household wellbeing value)	Roadworks (Aggregated wellbeing value of incident)
Average wellbeing value per incident (baseline model)	£449.91	£390,557	£39.91	£31,728
Wellbeing value of first incident (quadratic model)	£560.55	£486,557	(N/S)	(N/S)
Wellbeing value of second incident (quadratic model)	£328.01	£284,713	(N/S)	(N/S)

8 Bibliography

Diener, E. (2000). Subjective Wellbeing. The Science of Happiness and a Proposal for a National Index. *Am Psychol*, *55*(1), 34–43.

Diener, E., Suh, E. M., Lucas, R. E., & Smith, H. L. (1999). Subjective well-being: three decades of progress. *Psychological Bulletin*, *125*(2), 276–302. https://doi.org/10.1037/0033-2909.125.2.276

Dolan, P., & Fujiwara, D. (2016). Happiness-Based Policy Analysis. In *The Oxford Handbook of Well-Being and Public Policy* (pp. 286–317). New York, NY: Oxford University Press.

Eid, M., Langeheine, R., & Diener, E. (2003). Comparing Typological Structures Across Cultures By Multigroup Latent Class Analysis A Primer. *Journal of Cross-Cultural Psychology*, *34*(2), 195–210. https://doi.org/10.1177/0022022102250427

Frederick, S., & Loewenstein, G. (1999). Hedonic Adaptation. *Well-Being. The Foundations of Hedonic Psychology/Eds. D. Kahneman, E. Diener, N. Schwarz. NY: Russell Sage*, 302–329.

Fujita, F., & Diener, E. (2005). Life Satisfaction Set Point: Stability and Change. *Journal of Personality and Social Psychology*, *88*(1), 158–164. https://doi.org/10.1037/0022-3514.88.1.158

Fujiwara, D., & Campbell, R. (2011). *Valuation Techniques for Social Cost-Benefit Analysis: Stated Preference, Revealed Preference and Subjective Well-Being Approaches. A Discussion of the Current Issues* (pp. 1–76). London, UK: HM Treasury. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/209107/greenbook_valuationtechniques.pdf

Fujiwara, D., & Dolan, P. (2014). *Valuing Mental Health: How a Subjective Wellbeing Approach Can Show Just How Much It Matters* (p. 21). London, UK: UK Council for

Psychotherapy. Retrieved from http://www.psychotherapy.org.uk/UKCP_Documents/Reports/ValuingMentalHealth_web.pdf

Hicks, J. R., & Allen, R. G. D. (1934). A reconsideration of the theory of value. Part I. *Economica*, *1*(1), 52–76.

HM Treasury. (2011). *The Green Book: Appraisal and Evaluation in Central Government* (pp. 1–114). HM Treasury. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf

Kahneman, D., & Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk. *Econometrica*, *47*(2), 263. https://doi.org/doi:10.2307/1914185

Kimball, M., & Willis, R. (2006). Utility and happiness. *University of Michigan*.

Krueger, A. B., & Schkade, D. A. (2008). The Reliability of Subjective Well-Being Measures. *Journal of Public Economics*, *92*(8), 1833–1845.

NERA. (1998). *The Environmental and Social Value of Leakage Reduction (in context with other Resource and Demand Management Alternatives)*.

OECD. (2013). *OECD Guidelines on Measuring Subjective Well-being* (p. 265). Paris, France: OECD Publishing. Retrieved from http://dx.doi.org/10.1787/9789264191655-en

Pavot, W., & Diener, E. (1993). The affective and cognitive context of self-reported measures of subjective well-being. *Social Indicators Research*, *28*(1), 1–20. https://doi.org/10.1007/BF01086714

Pavot, W., Diener, E., Colvin, C. R., & Sandvik, E. (1991). Further Validation of the Satisfaction With Life Scale: Evidence for the Cross-Method Convergence of Well-Being Measures.

Journal of Personality Assessment, *57*(1), 149–161. https://doi.org/10.1207/s15327752jpa5701_17

Sales, S. M., & House, J. (1971). Job dissatisfaction as a possible risk factor in coronary heart disease. *Journal of Chronic Diseases*, *23*(12), 861–873. https://doi.org/10.1016/0021-9681(71)90015-4

Schimmack, U., & Oishi, S. (2005). The influence of chronically and temporarily accessible information on life satisfaction judgments. *Journal of Personality and Social Psychology*, *89*(3), 395–406. https://doi.org/10.1037/0022-3514.89.3.395

Veenhoven, R. (2007). Subjective Measures of Well-being. *Human Well-Being*, 214–239.