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#### How to cite:

Strathie, A.; Netto, G.; Walker, G. H. and Pender, G. (2017). How presentation format affects the interpretation of probabilistic flood risk information. *Journal of Flood Risk Management*, 10(1) pp. 87–96.

For guidance on citations see [FAQs](#).

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Version: Accepted Manuscript

Link(s) to article on publisher's website:  
<http://dx.doi.org/doi:10.1111/jfr3.12152>

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## **How presentation format affects the interpretation of probabilistic flood risk information**

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Some of the data discussed in this article was presented at the ICFR conference:

Strathie, A., Netto, G., Walker, G.H, & Pender, G. (September, 2013). *Communicating uncertainty in flood risk messages - understanding and risk perception*. International Conference on Flood Resilience, Exeter, UK.

### **Abstract**

In many European countries, flood awareness information is communicated through flood extent maps and probabilistic language. However, research suggests that probabilistic information is difficult to understand, and that presentation format affects understanding and risk perception. In this study, thirty participants participated in focus groups to explore responses to a flood extent map and completed a questionnaire to measure the effect of expressing the probability of flooding using different language formats on understanding and risk perception. Responses to the flood extent map reveal participants experienced difficulties interpreting the probabilistic information. In the questionnaire understanding was high across statements for both self-report and objective measures. However, the standard way of communicating risks, in terms of years per flooding event, evoked the lowest levels of understanding. For risk perception, there were differences in mean risk ratings across statements, and in general, people perceived the risk as greater when presented in terms of cumulative probability over a number of years, than in terms of the probability of a single event. This suggests that by making alterations to the standard format used to communicate probabilistic flood risk information it may be possible to increase understanding and awareness of the risks posed by flooding.

### **Keywords**

Risk; Risk Management; Social

### **Introduction**

The risks posed by flooding are a global problem. In Europe alone, the European Environment Agency reported that between 1998 and 2009 there were 213 major floods, which collectively resulted in the loss of 1126 lives and an estimated €52 million in financial costs (EEA 2010). While it is not possible to prevent natural events such as flooding from occurring, it is possible to mediate the potentially negative impact on homes and communities through effective flood management. The European Floods Directive 2007/60/EC (European Commission, 2007, p3) defines flood risk as the:

combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event.

The act requires Member States to assess whether water courses and coast lines are at risk from flooding, to map the flood extent, to establish the risk to people and assets, and to take measures to reduce this risk. Risk communication is of central importance to this process, and the way in which information is communicated has a direct effect on how people perceive their level of risk.

The aims of risk communication are threefold; to convince people that a risk exists, to describe the nature of that risk, and to advise people about the actions that can be taken to address the risk (Lundgren & McMakin 2009). However, achieving these aims in the context of flooding is challenging because flood forecasting is based on probabilities, not absolutes, and probabilistic information is not widely understood by laypeople (Visschers et al. 2009). Additionally, the type of risk information provided, and the format in which it is presented, may directly affect public perception and understanding of these risks (e.g. Siegrist 1997; Keller et al. 2006) The purpose of this paper is to address these issues by exploring public understanding and perception of probabilistic flood information presented in different formats, including through mapping flood extent.

### **Communicating Probabilistic flood risk information through language**

Although there is evidence that many people find probabilistic information difficult to understand (Visschers et al. 2009), support for incorporating this type of information when communicating flood risks comes from a number of sources. ‘The Pitt Review’ (Pitt 2008), an independent review of flood management systems in the UK, suggested that the inclusion

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of probabilistic information would be useful for professional partners, and a study conducted by The Department for Environment, Food and Rural affairs (DEFRA) and the Environment Agency (Kashefi et al. 2009) found support for the inclusion of probabilistic information in flood communication with members of the public. Similarly, a survey conducted by Frick & Hegg (2011) found that 'scientifically aware' laypeople welcomed information about forecast uncertainty in relation to flood messages, although there are likely to be large variations in the level of understanding and desire for this information among different sections of the public (Covello et al. 1986).

Under European Floods Directive 2007/60/EC, member states are now required to communicate flood risk to the public using language and flood maps that incorporate probabilistic information. In Scotland, the directive is incorporated in 'The Flood Risk Management (Scotland) Act' (2009), and responsibility for applying the act falls to the Scottish Environmental Protection Agency (SEPA). Currently, SEPA provide flood maps online, and communicate the probability of flooding in a given area in terms of a '1 in 200 year flood'. However, the extent to which the information provided by SEPA is understood by laypeople is uncertain. Furthermore, it is not clear how probabilistic information about flooding affects risk perception, which is also an important aspect of risk communication. The risk of flooding in the home is low for most individuals, and evidence suggests that people find it difficult to understand and interpret low probability risks (Bier 2001; Camerer & Kunreuther 1989), and might tend towards underestimating them in some circumstances (Keller et al. 2006). By exploring these issues it may be possible to optimise communication strategies to ensure appropriate levels of understanding and awareness.

Previous research on flood risk communication demonstrates that the terminology and phrasing used to communicate flood risk can impact on how well the information is understood. For example, the CRUE ERA-Net Research initiative conducted a study to explore understanding of risk statements phrased in several formats (Waylen et al. 2011). They found that participants understood the term "1 in 100 year flood" better than: "flood with a 1% annual exceedance probability", a "1 in 100 flood" or "a flood with a 1 in 100 chance of being equalled or exceeded every year". Understanding was primarily measured by self-report (asking the respondents if they understood the term). In general, the terms were poorly understood. Only 35% of respondents reported that they understood the phrase 'flood with a 1% annual exceedance probability,' and this rose to around 65% of participants who understood the phrase '1 in 100 year flood'. Some respondents in the study by Waylen et al.

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(2011) were also given an objective test of understanding, and were asked: “if the flood occurred today, when would it happen again?” The options were: “will happen in 100 years’ time” or “could happen any time”. If respondents chose the first option, they were judged to have misunderstood the probability statement. For the phrase ‘1 in 100 year flood,’ objective understanding was higher than self-reported understanding, while for the phrase ‘flood with a 1% annual exceedance probability’, the reverse was true. This is important because it indicates that people may be poor at judging their own level of understanding. Additionally, while those who answered the objective question correctly showed that they realised the statement did not indicate that floods would occur exactly 100 years apart, they may still have underestimated the risk. This suggests that measuring both understanding and risk perception is important in order to assess the impact of different formats used to present risk information.

Keller et al. (2006) explored the relationship between presentation format and risk perception for flooding events. Participants in their study saw the risk of flooding as higher when it was expressed over longer periods, in terms of cumulative probability, rather than in terms of the probability in a single year. For example, Keller et al. found that the statement ‘Within 40 years, there is a 33% probability of a flood’ was rated as indicative of a higher risk of flooding than the statement: ‘Each year, there is a 1% probability of a flood’ even though these relate to the same probability (a 1 in 100 year flood). Keller et al. suggest that this finding is consistent with participants making use of heuristics to inform their evaluations. For example, formats that present larger, cumulative probabilities may evoke emotional imagery. This emphasises the threat posed by the hazardous event, triggering the use of an ‘affect’ heuristic, whereby the emotional response acts as a cue to assess risk. This explanation is consistent with previous research (e.g. Rottenstreich & Hsee 2001), which indicates that people give greater weight to small probabilities when they have affect-laden outcomes. Alternatively, people may be influenced by an ‘availability heuristic’ (Kahneman & Tversky 1973), whereby probability is assessed based on how easily people can recollect examples of a hazard (e.g. flooding). However, Slovic et al. (2004) suggest that hazard events that are laden with affect may also be more ‘available’ for recollection, and as such these two heuristics may be interconnected.

Although research focusing solely on flood risk is limited, research on how the presentation of probabilistic risk information affects perception of other potential hazards (e.g. health and

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other environmental risks) offers complementary insights, and Keller et al.'s (2006) findings can also be interpreted as an example of 'base-rate neglect' (Tversky & Kahnemann 1973). This is the finding that people do not give sufficient consideration to population statistics when making judgements based on probabilistic information, and have a tendency to focus on the frequency of the numerator instead of the overall proportion (Kirkpatrick & Epstein, 1992). This effect is demonstrated in a study on health risks conducted by Yamagishi (1997), which found that participants viewed a risk of 1,286 out of 10,000 as greater than a risk of 24.14 out of 100, even though the reverse is true. In sum, these studies indicate that by presenting risks in a format that uses a larger numerator, it is possible to increase risk perception. However, other aspects of the format used to present risk information may affect perception, and also understanding, of the risk.

Gigerenzer & Hoffrage (1995) conducted a study to explore how presentation format affects understanding of probabilistic information by comparing frequency formats with percentage formats, using examples from a number of different contexts (e.g. medical, economic). Their findings suggest that numerical risk information is better understood when presented in the format of a frequency (e.g. 1 in 20) than when formatted as a percentage (e.g. 5% chance). However, Visschers et al. (2009) conducted a review of the literature on the communication of risk probabilities, combining insights from research on a number of different hazards (e.g. medical risks, accident rates, risks from natural hazards), in order to make recommendations about best practice, and found mixed evidence that frequencies optimise understanding. Based on their analysis across several studies, it is unclear whether frequencies are more easily understood than percentages, and further research is required to clarify this issue. However, while the effect on understanding is unclear, the evidence is that presenting numerical risk information in the form of frequencies increases peoples' perception of the risk. For example, participants presented with a high risk in a frequency format were willing to pay more for improved medication than participants who received the same information in a percentage format (Siegrist 1997). For the purposes of the current paper, this indicates that the format in which flood risk probability is communicated has not only important consequences for the extent to which risk information is understood by laypeople, but may also affect risk perception and estimates of personal vulnerability. This is important because research on health behaviour suggests that a person's risk perception and their willingness to engage in protective actions are related (Brewer et al. 2004).

### **Communicating Probabilistic flood risk information using maps**

Typically, probabilistic flood risk information is not communicated solely through language, rather it incorporates some visual information. A review by Charrière et al. (2012) identified maps as the most common means of visual risk communication. In communicating the threat posed by natural hazards such as flooding, the spatio-temporal component of the risk is important, and maps offer a useful tool to convey this information (Dransch, Rotzoll & Poser 2010). An effective flood map can raise awareness and encourage users to seek further information (Hagemeyer-Klose & Wagner 2009), but care must be taken in their design to ensure that they are not open to misinterpretation (Bartels & van Beurden 1998). Additionally, Hagemeyer-Klose & Wagner (2009) identify that people prefer maps that offer sufficient detail to allow them to locate their own streets, and previous research (e.g. Excimap 2007; Hagemeyer-Klose & Wagner 2009) suggests that the choice of colours used to display risk on the map is important. The colours chosen should both stand out from the map background, and also fit with people's existing colour associations (e.g. red = danger).

Fuelled by the introduction of European Floods Directive 2007/60/EC in 2007, the last two decades have seen an expansion in the use of flood maps across the continent (De Moel et al. 2009; Dransch et al. 2010), but there are variations in the types and styles of maps which are produced in each country. De Moel et al. (2009) conducted a review of the flood maps used in Europe and found that flood extent maps were the most common type, and were used in 23 countries, including Scotland. However, according to Dransch et al. (2010) the presentation format and its effect on risk perception have not been systematically explored during the map design process.

Many of the flood extent maps in use in Europe are also available to the public (De Moel et al. 2009; Charriere et al. 2012) but there is little evidence that the needs of a specific target group are given explicit consideration in the design of the maps (Charriere et al. 2012). Charriere et al. highlight that although the public are the most frequent target group of publicly available flood maps, most studies have focused on maps produced for risk managers, and studies on the effect of flood maps on public perception and understanding are less common. However, as highlighted by previous research, probabilistic information may be difficult for the public to understand, and more information is required about how flood extent maps are perceived by the public.



## **Current Study**

The current investigation examines how people perceive and understand risk information in relation to flooding across different presentation formats, incorporating both quantitative and qualitative research methods. The inclusion of a qualitative dimension allows exploration of factors that might either facilitate or hinder understanding of flood risk information, including word choice and contextual factors, which might not be revealed through quantitative research alone.

## **Participants**

Research participants were initially recruited through Heriot-Watt University's internal communication mechanisms with recruitment targeted at adults employed in non-academic roles, to supplement community-based recruitment strategies. Fifteen adults, the majority of whom had not experienced flooding at their properties, were recruited using this method. Another fifteen adults were recruited from the neighbourhoods of Currie and Balerno in Edinburgh, which are identified by SEPA's Flood Extent Maps (SEPA 2010), as areas at risk of flooding. The research was publicised in these areas using posters and leaflets. Thirty adults in total (twelve male, eighteen female) took part in the study. Their ages ranged between 20 and 81 years. Participants predominantly resided in the Edinburgh area. Eleven of the thirty participants reported that they currently live within 100 metres of a water body. Thirteen participants reported having experienced flooding. Participants received £20 in return for their time.

## **Design**

### *Probabilistic Statements*

In the first part of the study a questionnaire was used to explore understanding and risk perception in relation to probabilistic risk information presented in different formats. Following Keller et al. (2006), the study examined the effect of expressing probability over different time periods. Three different time periods were compared (single event probability, cumulative probability over 25 years, or cumulative probability over 100 years). The study also examined the effect of presenting the information in the format of a frequency or a percentage. This combination of factors produced six risk statements, which were compared to a seventh statement that represents current SEPA practice (1 in 200 year flood). Risk

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perception was measured by asking participants to provide ratings on a scale. Understanding was measured through self-report and by accuracy on an objective test.

### *Flood Extent Map*

In this part of the study, focus group discussions were centred on participants' perceptions of a map depicting flood extent, the most widely used representation of flooding in Europe (Hagemeier-Klose & Wagner 2009), which incorporates probabilistic information about the risk of flooding in different areas. The study examined the 'ease of understanding' and 'usefulness' of the map by asking participants to rate the map on these attributes using a 5 point scale (with 5 being the highest rating). Qualitative discussion of participant responses to the map then took place.

### **Materials and Procedure**

Participants read an information sheet describing the nature of the research and signed a consent form agreeing to take part in an hour long session on flood risk communication, incorporating a questionnaire and focus group discussion.

### *Probabilistic Statements*

A paper questionnaire was administered and each participant completed this individually, but could ask the researchers if they required clarification on any of the questions. Participants viewed seven risk statements, all of which represent the same risk probability, presented in different formats. Each was presented on separate pages. The seven statements are listed below.

- 1 in 200 year flood
- 0.5% chance that flooding will occur in this area in any given year.
- 1 in 200 chance that flooding will occur in this area in any given year.
- 11.8% chance that flooding will occur in this area at least once within 25 years.
- 39.4% chance that flooding will occur in this area at least once within 100 years.
- 11.8 times out of 100, flooding will occur in this area at least once within 25 years.
- 39.4 times out of 100, flooding will occur in this area at least once within 100 years.

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Measures of self-reported understanding, objective understanding, and risk perception were gathered for each statement using a questionnaire. The questions were listed beneath each risk statement, and were as follows:

a.) Do you understand what this phrase means? (Please circle one answer)

Yes/No

b.) How would you rate the risk of living somewhere when you have been told that, based on forecasts, there is a 1 in 200 year flood risk? (Please circle the number on the scale that matches your rating)

No Risk						Severe Risk
1	2	3	4	5	6	

c.) Imagine you live somewhere with a forecast that this is a 1 in 200 year flood risk area, and a flood occurred in your area this year. Based on this information, is it possible for another flood to occur in your area next year?

(Please circle one answer)

Yes/No

Following this, participants were presented with all seven statements simultaneously and were asked to select which of the seven statements they found easiest to understand.

### *Flood Extent Map*

As part of the focus group discussion, the flood extent map in figure 1 was projected on to a large screen. The design of the map was informed by a review of flood maps in Europe conducted by De Moel (2009) which identified that most European flood extent maps depict flood extent over three return periods, and use different colours/shades to represent each return period. Participants were asked to record their responses to two questions about the map via a button press, from 1 to 5, using an interactive 'clicker' system from Turning Technologies.

FIGURE 1 HERE PLEASE

*Figure 1: Flood Extent Map*

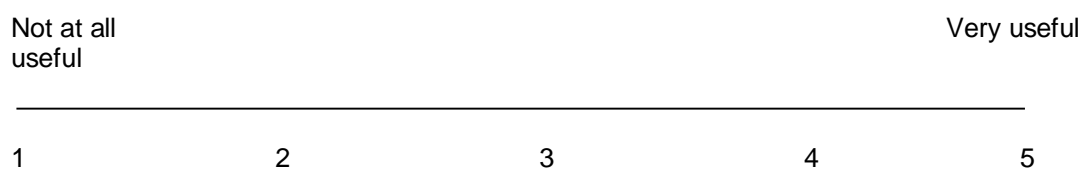
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Participants provided ratings in response to the following two questions:

How easy is it to **understand** this map?



How **useful** is the information in this map?



The aggregate responses were then projected on a screen, and these served as a basis for qualitative discussions of the map and the probabilistic information, allowing participants to explain the reasons for their ratings and to discuss their views with other members of the groups, thus providing both an individual and an interactive dimension to participants' understanding of flood risk probability.

## Results and Discussion

### *Risk Perception*

The descriptive statistics suggest that the different formats used to present probabilities in the seven risk statements had an effect on the perceived risk level. Median perceived risk levels and Interquartile Range (IQR) for each statement are summarised in Table 1.

Table 1: Median perceived risk and interquartile range

TABLE 1 HERE PLEASE

From this, it can be seen that Statements 1 (1 in 200 year flood), 2 (0.5% chance that flooding will occur in this area in any given year), and 3 (1 in 200 chance that flooding will occur in this area in any given year) have the lowest median ratings (all  $MD = 2$ ). Statement 4 (11.8%

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chance that flooding will occur in this area at least once within 25 years) has the highest Median rating ( $MD = 3.5$ ).

The differences across statements were analysed using a related-samples Friedmann test. The results revealed a statistically significant difference in perceived degree of risk across the different statements,  $\chi^2(2) = 57.96$ ,  $p < .05$ . Post-hoc analysis using Wilcoxon signed-rank tests with a Bonferroni correction was conducted to identify the source of the differences. These revealed that: Statement 4 ( $MD = 3.5$ ) differed significantly from Statements 1 ( $MD = 2$ ,  $z = -4.103$ ), 2 ( $MD = 2$ ,  $z = -4.103$ ), and 3 ( $MD = 2$ ,  $z = -3.373$ ). Statement 7 ( $MD = 3$ ) differed significantly from Statements 1 ( $MD = 2$ ,  $z = -3.921$ ), 2 ( $MD = 2$ ,  $z = -3.921$ ), and 3 ( $MD = 2$ ,  $z = -3.191$ ). Statement 5 ( $MD = 3$ ) differed significantly from Statements 1 ( $MD = 2$ ,  $z = -3.434$ ), and Statement 2 ( $MD = 2$ ,  $z = -3.434$ ). All at  $p < .05$ . The other contrasts were not significant ( $p > .05$ ). The results of this analysis suggest that the wording of the statements altered participants' perceptions of the risk level posed by a 1 in 200 year flood. To summarise, statements 4, 5, and 7 ('11.8% chance that flooding will occur in this area at least once within 25 years', '39.4% chance that flooding will occur in this area at least once within 100 years,' '39.4 times out of 100, flooding will occur in this area at least once within 100 years') elicited significantly higher risk ratings than statements 1 and 2 ('1 in 200 year flood', and '0.5% chance that flooding will occur in this area in any given year'). Statements 4 and 7 also received significantly higher risk ratings than Statement 3 (1 in 200 chance that flooding will occur in this area in any given year).

The significant differences were all between statements that expressed risk in terms of cumulative probability vs. those who described it in terms of the risk in any given year, though the ratings for Statement 6 were not significantly higher than the single year probability statements. These findings suggest that risks expressed in terms of their cumulative probability (e.g. 11.8% chance that flooding will occur in this area at least once within 25 years), rather than in terms of their probability in any individual year (e.g. 0.5% chance that flooding will occur in this area in any given year), increase the perception of risk. This result is consistent with the findings of Keller et al.'s (2006) research on cumulative flood risk probability. As there were no significant differences between statements 4, 5, 6, and 7, there is no evidence that presenting the information using frequencies vs. percentages altered levels of risk perception.

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Overall, the key findings are that three of the four risk statements elicited higher risk perception ratings than the current practice '1 in 200 year flood'. Two that expressed probability in terms of cumulative percentage chance of flooding (over 25 and 100 years) and one that expressed the risk in terms of cumulative frequency over 100 years. These findings are consistent with previous research suggesting that people neglect information about population statistics when making risk judgements (Tversky & Kahnemann 1973) and tend to focus on the numerator at the expense of the denominator (Yamagishi 1997). Therefore, cumulative presentation formats may be a more appropriate means to communicate information where there are concerns that people currently neglect or underestimate their risk of flooding.

### *Understanding*

Table 2 summarises the results for self-reported understanding and objective understanding, and the number of people who chose each statement as being the easiest to understand. Although they were asked to select one option, some participants chose two options, and this is recorded in the table. The results show that in our sample, understanding was high across risk statements, and for each of the statements, between 70 – 90% of the 30 respondents reported that they understood the information. The self-report measure was supported by the answers to the comprehension test, with 70 – 97% of participants answering this question correctly across statements. This suggests that most people in our sample were able to correctly interpret the probability statements. Interestingly, the descriptive statistics show that, in general, objective understanding ratings were slightly higher than self-reported understanding.

The percentage of participants who understood the statements in this study is higher than in previous research (e.g. Waylen et al. 2011), which may suggest that the wording of the risk statements is easier to understand, or that our group of participants had greater familiarity with probabilities. However, another possibility is that because the participant group was small, and participants were unevenly spread across sessions, it wasn't possible to randomise the order in which the risk statements were presented. As a result, individuals may have recognised that the seven statements described the same probability in different formats, and built up an understanding of the statements as they progressed. This may explain why the

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error rate was higher for the first statement (1 in 200 year flood) than the other statements, and, this is an issue that will be addressed in future research.

The self-report measure of understanding required binary responses (yes or no), but a few respondents suggested that it was difficult to categorise their understanding of the risk statements, as they were sometimes unsure if they really understood the statements. Therefore, rather than reflecting actual levels of understanding, the high number of correct answers in this study may result from the relative simplicity of the question posed, and the forced choice response options. However, the question used here is similar in format to that used by Waylen et al. (2011) and the percentage of participants who answered the comprehension questions correctly in their study was lower than the figures obtained here. This suggests that either this group of participants had higher familiarity with probabilities, or that the statements used in the current study were easier to understand than those in previous research. The relatively high levels of education of the sample may also have contributed to higher understandings of probability statements than in previous research.

Table 2: Statement preference, objective understanding and self-reported understanding across risk statements

TABLE 2 HERE PLEASE

Participants were asked to choose which of the seven statements they found easiest to understand. The statements most people understood as measured by the objective test were Statement 4 ('11.8% chance that flooding will occur in this area at least once within 25 years') and Statement 7 ('39.4 times out of 100 flooding will occur in this area at least once within 100 years'). However, when participants were asked to select the statement that they found easiest to understand, they favoured Statement 2 ('0.5% chance that flooding will occur in this area in any given year'), and Statement 3 ('1 in 200 chance that flooding will occur in this area in any given year'). Twenty-six people reported that they understood Statement 2 and twenty-seven reported that they understood Statement 3. Comparable numbers of participants reported that they understood Statements 4 (11.8% chance that flooding will occur in this area at least once within 25 years), and 5 (39.4% chance that flooding will occur in this area at least once within 100 years), yet when selecting an overall

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preference, these statements were selected by few of the participants (one and three respectively). Interestingly statements 2 and 3 are associated with lower levels of risk perception than statements 4 and 5, so it is possible that when asked to indicate a preference, people based their decisions on risk perception as well as understanding, and where understanding was equal, opted for statements associated with lower risk perception.

In sum, the findings here are mixed in terms of optimising understanding of probabilistic information. However, the format currently used by SEPA appears to be the least well understood, and also contributes to lower risk perception than several alternative formats.

### *Flood Extent Map*

The map incorporated probabilistic information about flooding on a flood extent map, which is the type of map currently used by SEPA. Three different shades of blue were used to indicate different return periods, with the lightest shade denoting areas affected by a 1 in 100 year flood, the middle shade denoting a 1 in 50 year flood, and the darkest shade denoting a 1 in 10 year flood. This means that flood risk is depicted at three discrete levels.

Based on the clicker responses, the map received a positive rating for usefulness (Median = 4.5) and the same value for understanding. Discussions structured around these aspects of the map, incorporating the map design and the probabilistic information.

In terms of design features the use of colour and shading was discussed, with the development in the degree of shading from light to dark seen as facilitating understanding of the risk level for some participants:

*'I know it sounds daft, but it is like the way they gone, it is the more intense flooding is the darker colour. Sometimes, something as simple as that, you look at that straightaway, you almost don't need to look at the key to see, intense/less intense.'*  
(Female, HWU Staff)

Others indicated a need for more information, and sought detail that was unavailable in the map at this scale, and revealed a concern with the vulnerability of individual properties:

*'Yes, I'd like to see the line of the river.'* (Male, HWU Staff)

*'So you could pick out your house more clearly.'* (Female, HWU Staff)

With regards to the visual depiction of risk, the discussions revealed that participants approved of the use of darker shades to indicate higher risks, and blue was viewed as a logical choice to indicate flood extent. Although it was not raised as an issue by the



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participants in this study, a sizeable proportion of the population experiences impaired colour perception (Deeb, 2005), so in future, the colours and shades should be varied in terms of lightness, saturation and hue to make them more distinguishable for people with different forms of colour blindness (Wong, 2011). A further consideration is that by presenting the visual flood extent information overlaying the map, it may be difficult for people to distinguish geographic information that is needed to help them identify locations, particularly elements such as rivers, which are the same colour as the overlay. This issue was raised by some of the participants, and is something that could be explored in future research.

On the issue of the flood extent information, the inclusion of probability was seen as an advantage for some discussants:

*'The risk is displayed, it's pretty good.'* (Male, HWU Staff)

*'It breaks it down as to when you could possibly expect flooding in the area'* (Female, HWU staff)

However, although the map received a high rating for ease of understanding, the comments suggest that the inclusion of probabilistic information caused concerns for some discussants:

*'I would put it down as harder for folk to understand because you're going into the realms of possibilities here. Chance.'* (Male, Currie resident)

Additionally, the perceived risk associated with the probabilistic information risk differed across individuals as illustrated in this exchange:

*M1: 'So what they are saying, that even at the 1 in 100 year risk, it's telling you that there's a possibility. But the way that it's coming across it's putting the perception at such a distance.'* (Male, Currie resident)

*M2: 'That's right. You think it's highly unlikely in my life.'* (Male, Currie resident)

*F: 'So you find it reassuring'.* (Female, Currie resident)

*M2: 'It doesn't make it....you could think it was reassuring, but it doesn't reassure me.'*

While the participants in this extract show awareness that the wording might lower risk perception and create a false sense of security, other comments show that not all participants understood this means of communicating flood risk probability or were familiar with it:

*'The 1 in 200 years and 1 in 20, to me they are just meaningless. Which part of the 100 years are you in? I don't think it tells you anything at all.'* (Female, Currie resident)

*'I hadn't heard the expression, 1 in 10 year floods before today.'* (Male, Currie resident)

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Scepticism about estimated probability was also expressed:

*'Just, I think, nowadays they are having (sic) to rethink the figures. Things they thought were going to happen once in 100 years is (sic) happening a lot more often now'* (Female, Balerno resident)

*'No, I don't think anybody can be absolutely certain on anything (sic) like this is going to be in the future'* (Male, Balerno resident)

Some respondents also had concerns about how well the map represented environmental changes, questioning whether these might mean several flooding events could occur in close succession:

*'There is no information about the likelihood of events going on. Like things that are happening, to do with the weather making it more likely that there will be a flood. Like, what if you get 30 years in 3 years? Like, you get it 3 times.'* (Female, Balerno resident)

While the results of the quantitative study suggested that levels of understanding of probabilistic information were quite high, the focus group discussions reveal that the flood risk information was not universally understood, and that some of the terminology needs to be clarified. Also, consistent with the quantitative findings, risk perception varied across individuals, suggesting that individual factors such as personal experiences of flooding may alter levels of risk perception and awareness.

## Conclusions

By advancing understanding of effective strategies for communicating risk of flooding, it may be possible to increase preparedness against flooding, and mitigate against the damaging impacts of flooding on properties and lives. This study advances understanding of communication of probability of flood risk - an area of research that is in its infancy - in three main ways. Firstly, it provides additional evidence that the language used to communicate probabilistic information has an effect on understanding and perception of flood risk. Combined with previous research by Keller et al. (2006) on flood risk perception, the results suggest that more attention needs to be paid to the format used to present risk information, in order to influence risk perception and to narrow the gap between the estimated and perceived risk of flooding.

Secondly, the study reveals that SEPA's current practice for communicating the probability of flooding (1 in 200 year flood) was understood by the fewest participants, as measured by both self-report and objective test, which highlights the need for revision. In terms of

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identifying the presentation format that is most effective for optimising understanding, the results are more ambiguous. Based on the quantitative study, understanding of risk probabilities was high among our sample, so it is difficult to identify one set of phrasing as optimal. Although a relatively large number of people successfully passed the objective probability test in our study, the high levels of education in the current sample may misrepresent the level of understanding of risk statements among the wider population. However, the focus group discussions highlighted that even among this relatively well-educated sample, there are still some difficulties in interpreting this type of information, indicating the need for more attention to be paid to developing strategies for raising flood risk awareness among a more diverse population.

Thirdly, the study indicates that aspects of both map design and probabilistic information should be taken into account when communicating the risks of flooding. The focus group discussions suggested that the use of maps to convey information about flooding was well received, and in terms of design, respondents welcomed the use of colours that made intuitive sense, which supports previous research findings (e.g. Excimap 2007; Hagemeyer-Klose & Wagner 2009) suggesting that people prefer intuitively logical colour schemes (e.g. blue = water) and good differentiation between shades.

The results also offered empirical support for the use of finer-grained maps with more detail about potential flooding locations, so that individuals can understand where their own street lies in relation to the risk. The findings reinforce previous research (e.g. Bartels & van Beurden 1998) that information provided in maps can easily be misinterpreted, and that technical terminology should be avoided where possible, or should be clearly explained. Discussion of the probabilistic information in the focus groups complements the findings of the quantitative study by identifying aspects of probabilistic risk information that are difficult to understand. Additionally, the richer data supplied by the focus groups helps to identify the confusion that can arise through the use of specific probability statements.

Despite the widespread use of flood extent maps across Europe, there is relatively little research on how flood extent maps are perceived and understood by the public, so the results of this study offer a useful starting point to begin addressing this knowledge gap, and several issues that warrant further investigation have been identified. The results of this study could be used to inform future map designs, and subsequent iterations could be tested with members of the public to assess understanding and risk perception. This would allow map

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designers to take into account variation in understanding and perception across the population, so that the maps could be adapted for different target groups. Further research is required to clarify the different factors that can influence understanding of risk messages. Follow-up research is planned that will use an experimental approach, where different risk probabilities can be presented, and randomisation and counterbalancing employed, in order to clarify how different message formats impact on understanding. Similarly, the effect of other factors such as prior experience of flooding could be examined with a larger, more diverse sample. Additional qualitative research could also help identify which aspect of the probabilistic information is difficult for people to interpret.

In sum, the study identifies that laypeople do experience difficulties with understanding and interpreting probabilistic risk information, and the method used to present the information can alter public perception and understanding of the risks posed by flooding. By presenting information in a form that increases the perceived level of risk, it may be possible to increase preparedness against flooding and reduce the number of people who neglect the risk, thus mitigating the damaging impacts of flooding on properties and lives. However, as there is evidence that presenting probabilistic information in cumulative form induces higher risk perception, care should be taken to ensure that risk probability is not communicated in a format that produces a response that is disproportionate to the risk posed by the hazard. Thus, in order to optimise the effectiveness of communication, it is important both to increase understanding of the risks, and to ensure that a person's perception of the potential risk is proportionate.

### **Acknowledgements**

The Authors wish to thank the participants that took part in the research, and everyone that contributed to the design and execution of the project. Input from SEPA was invaluable in developing the research tools, and the work described in this publication was supported by funding from the James Hutton Institute, through the Centre for Research in Water Expertise (CREW).

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**Figures and Tables**

*Figure 1: Flood Extent Map*

Table 1: Median perceived risk and interquartile range

Table 2: Statement preference, objective understanding and self-reported understanding across risk statements

Table 1: Median perceived risk and interquartile range

Statement No.	Risk Statement	Median Rating (IQR)
1	1 in 200 year flood	2 (2 - 3)
2	0.5% chance that flooding will occur in this area in any given year	2 (2 - 3)
3	1 in 200 chance that flooding will occur in this area in any given year	2 (2 - 3)
4	11.8% chance that flooding will occur in this area at least once within 25 years	3.5 (3 - 5)
5	39.4% chance that flooding will occur in this area at least once within 100 years.	3 (2.75 - 5)
6	11.8 times out of 100, flooding will occur in this area at least once within 25 years.	3 (2 - 5)
7	39.4 times out of 100, flooding will occur in this area at least once within 100 years.	3 (3 - 5)



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Table 2: Statement preference, objective understanding and self-reported understanding across risk statements

Statement No.	Risk Statement	No. of participants who preferred this/these statement(s)	No. of participants (out of 30) who understood this statement (objective test)	No. of participants (out of 30) who reported understanding the statement (self-rep)
1	1 in 200 year flood	5	21 (70%)	21 (70%)
2	0.5% chance that flooding will occur in this area in any given year	9	25 (83%)	26 (87%)
3	1 in 200 chance that flooding will occur in this area in any given year	9	28 (93%)	27 (90%)
4	11.8% chance that flooding will occur in this area at least once within 25 years	1	29 (97%)	26 (87%)
5	39.4% chance that flooding will occur in this area at least once within 100 years.	3	28 (93%)	27 (90%)
6	11.8 times out of 100, flooding will occur in this area at least once within 25 years.	1	28 (93%)	21 (70%)
7	39.4 times out of 100 flooding will occur in this area at least once within 100 years.	0	29 (97%)	25 (83%)
	Risk Statement 2 & Risk Statement 7	1		
	Risk Statement 4 & Risk Statement 5	1		