Flood forecasts and decision-making

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Floods are natural phenomena that cannot be prevented. Flood risk management attempts to reduce the adverse effects of floods. One flood risk management measure comprises using forecasts to decide whether or not to set up temporary flood barriers. The present document comprises a computational example of this measure, explains the theoretical background and shows how forecasts can be used to inform a decision.

Computational example

Suppose that a supermarket is located in a flood prone area. A flood will cause $1M damage. The supermarket has the option to set up temporary barriers; this will cost $100,000 (most of this cost is due to the supermarket having to temporarily shut down). The barrier will prevent any flood damage from occurring.

Let's use a hypothetical series of 1,000 independent situations where a flood is forecast with 20% probability. We elaborate the following scenarios:

- In all 1,000 situations, the supermarket will set up the temporary barrier;

- In none of the 1,000 situations, the supermarket sets up the temporary barrier.

Figure 1: Temporary flood barriers. Photo credit: Boxbarrier b.v.

* Expected number of floods

The 1,000 situations and the 20% probability means that there will be approx. 200 floods and 800 non-flood situations.

* Barriers installed

If, in all 1,000 situations, the supermarket will set up the temporary barrier then it incurs 1,000 × \$100,000 in costs: \$100M in total. The 200 floods will not have caused any flood damage.

* Barries not installed

If the supermarket never sets up the temporary barriers then the 200 floods will result in 200 × \$1M damage: \$200M in total. The 800 non-flood events will not cause any flood damage and as barriers were never employed, there are no associated costs.

In a table:

	Costs	Damage	Total
Scenario 1: barriers installed	\$ 100M	\$ -	\$ 100M
Scenario 2: no barriers installed	\$ -	\$ 200M	\$ 200M

In this combination of flood probability (20%), flood damage ($1M) and costs of a measure ($100k), the supermarket would be best off by always installing the barrier. That raises a question, however: at which level of probability do the barriers need to be installed?

Below graph shows the total of flood damage and mitigation costs for the two scenarios, as a function of the probability of flooding. Scenario 1 - where barriers are always installed - is not dependent on the probability (or rather, the number) of floods. Scenario 2 is linearly dependent on the number of floods, as every flood will result in flood damage ($1M per flood).

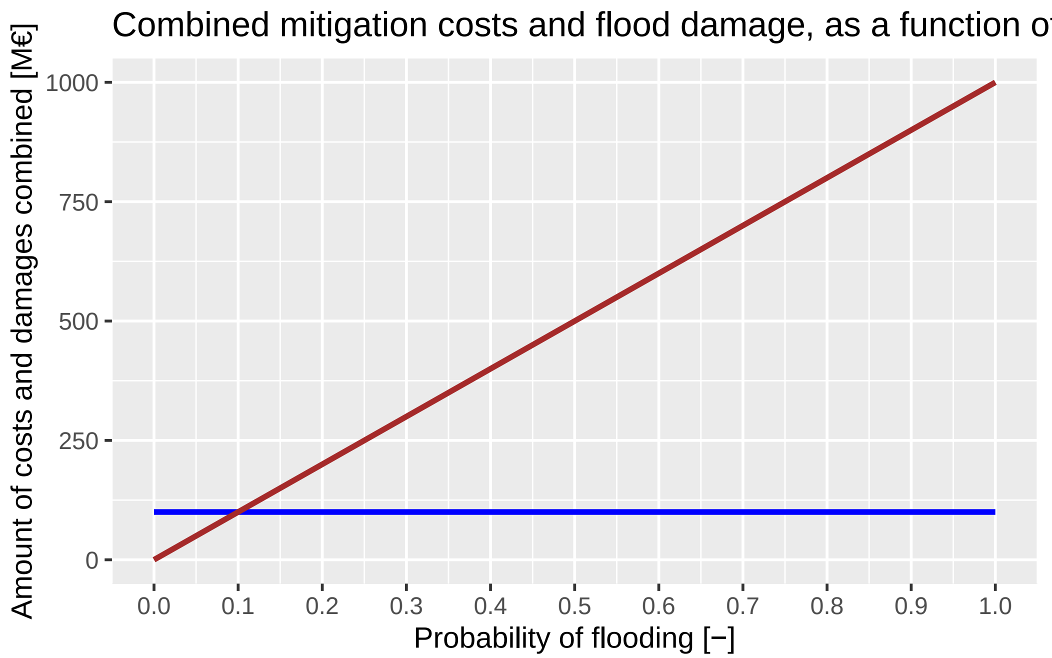

Figure 2: Costs and damage as a function of flood probability

The graph shows that from a probability of 0.1 (i.e., from 10%) onward, it is more cost-efficient to install barriers than to not install barriers.

Theory: cost-loss ratio

Above criterion can be theoretically proven using the so-called *cost-to-loss criterion* (Murphy, 1977; Verkade and Werner, 2011). We define two scenarios:

- **scenario 1** where flood mitigation measures are pre-emptively taken;
- **scenario 2** where no flood mitigation measures are taken.

We also define the following variables:

- probability of flooding P
- unmitigated flood damage L
- avoidable flood damage ΔL
- cost of flood damage mitigation C

In scenario 1, the sum of costs and expected damage equals the cost of flood mitigation C plus the damage that cannot be avoided, (even when flood damage mitigation measures are in place) $L - \Delta L$ times the probability of flooding P. In scenario 2, there *is* no mitigation hence the expected damage is equal to the probability of a flood P times the unmitigated flood damage L.

Flood mitigation measures are taken if - and only if - the expected cost/damage of the 'mitigation' scenario 1 is less than or equal to the expected damage of the 'no mitigation' scenario 2.

$$E_1 \leq E_2 \tag{1}$$
$$C + P \times (L - \Delta L) \leq P \times L \tag{2}$$
$$C + P \times L - P \times \Delta L \leq P \times L \tag{3}$$
$$C - P \times \Delta L \leq 0 \tag{4}$$
$$C \leq P \times \Delta L \tag{5}$$
$$C/\Delta L \leq P \tag{6}$$
$$P \geq \frac{C}{\Delta L} \tag{7}$$

This equation $P \geq C/\Delta L$ means that we initiate flood damage mitigation measures if - and only if - the flood probability P exceeds the ratio of flood damage mitigation costs C over avoidable flood damage ΔL.

In the previous example, the flood damage mitigation costs C equaled \$100k and the avoidable flood damage ΔL equaled \$1M.

$$P \geq \frac{C}{\Delta L} \tag{8}$$
$$P \geq \frac{\$100\text{k}}{\$1\text{M}} \tag{9}$$
$$P \geq 0.1 \tag{10}$$
$$\tag{11}$$

which means that we decide to set up the temporary flood barriers if and when the probability of flooding equals 0.1 or higher. Indeed, this is what was shown in Figure 2.

Using the forecasts

Suppose that we're interested in location where the flooding threshold is at 50 m3/s. Figure 3 shows the most recent 40-scenario forecast. From the forecast, we can identify the scenarios in which the flood threshold is exceeded. In the graph, these are highlighted in red.

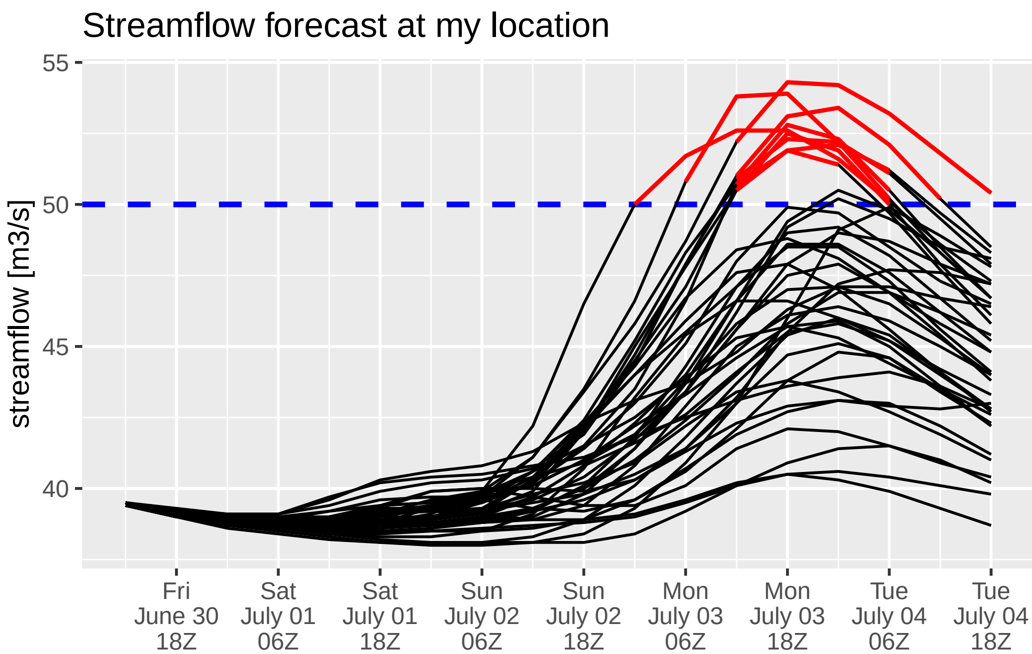

Figure 3: Most recent forecast for my location of interest

In this particular forecast, 11 out of 40 scenarios show an exceedance of the flood level. That corresponds to a probability of 0.275, or 27.5%. Going by the computational example above, with a cost-to-loss ratio of 0.1 (or 10%), this forecast would result in a decision to initiate flood damage mitigation measures.

About Deltares

Deltares is the Dutch national R&D institution in the field of water management and geotechnical engineering. Deltares operates **gloffis**, a global, real-time hydrological forecasting system. The system allows for estimating future flood conditions, with a lead time of up to 10 days and future drought conditions, with a lead time of up to 4 months. The system produces both 'best estimate' conditions as well as probabilistic estimates of future conditions. In addition to the provision of real-time forecasting services, Deltares can assist in the development of appropriate decision rules.

The **gloffis** team is ready to talk to you about your forecasting requirements. Feel free to set up a meeting.

References

Murphy, A. H.: The value of climatological, categorical and probabilistic forecasts in the cost-loss ratio situation, Monthly Weather Review, 105, 803–816, 1977.

Verkade, J. S. and Werner, M. G. F.: Estimating the benefits of single value and probability forecasting for flood warning, Hydrology and Earth System Sciences, 15, 3751–3765, https://doi.org/10.5194/hess-15-3751-2011, 2011.