# Info-gap assessment of cost-effectiveness for flood-mitigation scenarios: Haigh Beck case study

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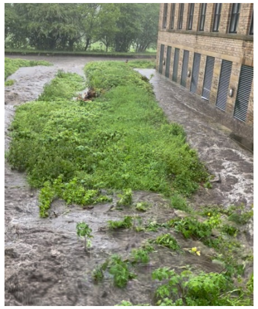
Sharing is encouraged

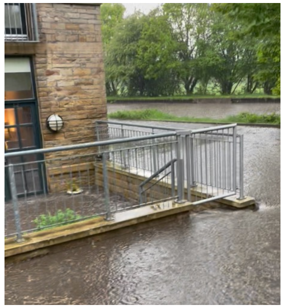
## Haigh Beck & graphical cost-effectiveness tool

***Goal & outcome: value (NBS) unvalued co-benefits!*** *Case study:* Urban ***Haigh Beck*** runs 2000m from spring to River Aire with 100m drop, flows into/under canal, culverted last 200m. Surface flooding occurs in neighborhoods near river & canal at ~1:15yrs AEP. New flood defense walls near river cover 1:200yrs AEP but trap beck: limited pump action $Q_T$=0.245m$^3$/s. Canal segment for large (extra) flood storage between two locks is 7.5kmx10mx1.5m with several overflows. CSO pollutes beck.

**Flooding, polluted, 06-05-2024 of 6 Bradford apartments** (~1:15yrs AEP):



Haigh Beck-canal-Dyehouse Mill
https://www.youtube.com/shorts/T9mH2MQkA3s



canal-apartments of Mill
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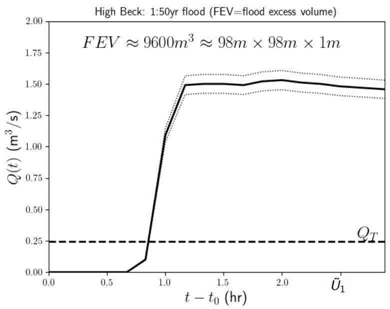
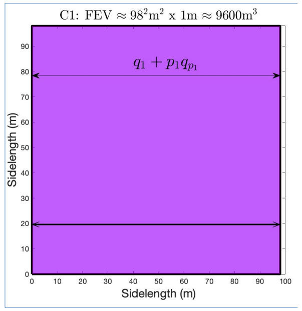
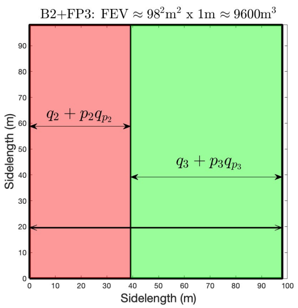



***Flood—Excess Volume (FEV)*** is volume that causes damage [1]; ~numerical modelling (LCC/BDMC) 1:50yrs Haigh Beck flood:

FEV = $\int_{t_0}^{t_0+T}$ Q(t)-$Q_T$ dt= 9600m$^3$ = 98x98x1m$^3$ sense of size!




| Measure | Base cost $q_i$ ($k£$) | Probability $p_i$ (/50yrs) | Damage $q_{p_i}$ ($k£$) | Total ($k£$) |
|---|---|---|---|---|
| **C1** | 500(900) | 1 | 70 | 570(970) |
| **B2** | <u>385</u> | 0.25 | 200 | 435 |
| **FP3** | <u>400</u> | 0.05 | 200 | 410 |
| **B2+FP3** | - | - | - | 845 |

***Base costs, probabilities & damage costs:***
To obtain estimate for $q_{p1}$, start from ￡1.7M repair costs of a culvert breach, emptying 60km of the Leeds-Liverpool canal (2021-2022 CRT). Since the canal stretch involved in C1 is 7km, 1/8 of those costs are involved so ~￡210k, of which ￡140k are standard costs occurring even in the absence of flood storage in the canal, so ￡70k extra investment. Base costs: C1 $q_1$= ￡500k, plus extra costs for (optional) 200m pipeline to separate CSO from beck ￡400k (clean-up). ***Real figures impossible to obtain in real cases*** (~10xFOIs!), $q_2+q_3$=785k given; rest estimated, e.g., $q_{p2}=q_{p3}$=￡200k, see Table above.

**Flood-mitigation scenarios** shown in square-lake graphs [1,2,3,4]:
**C1** *canal*: beck diverted into canal, automated gate to divide water into canal/culvert, coverage of $\alpha_1$xFEV with $\alpha_1$>1, <u>*costs*</u> $q_1+p_1 q_{p1}$, excess FEV coverage. Benefits **N**ature-**B**ased **S**olutions: anti-drought, clean canal, extra storage for climate change; split CSO spills split from beck to limit/cut **C**ombined **S**ewer **O**verflows; extra <u>costs</u> -$B_{11}=q_{1CSO}$.
**B2+FP3** *bund & flood-plain storage*: 1.0xFEV. **B2** *upstream bund*: in flatter areas, partial prevention $\alpha_2$xFEV with $\alpha_2$=0.4, <u>costs</u> $q_2+p_2 q_{p2}$. **FP3** culvert from canal to river opened at playing fields (protective flood plains), pumping needed, partial prevention $\alpha_3$ xFEV with $\alpha_3$=0.6, <u>*costs*</u> $q_3+p_3 q_{p3}$.

***Utility functions $U_1$ and $U_2$***:
$U_1 = \sum_{j=1}^{2} w_j C_j$ <u>without co-benefits,</u> weights $w_j$=0,1. **B2+FP3** best.
$U_2 = \sum_{j=1}^{2} w_j C_j - \sum_{k=1}^{N_j} a_{jk} B_{jk}$ <u>with co-benefits</u> $B_{jk}$, $B_{2k}=0$, $N_1=5$.
Take $B_{11}$ = - $q_{1CSO}$ = ￡ *400k* (no pollution beck/canal).
**But value benefits unknown**: $B_{12}= q_{1cc}$ (extra climate-change canal storage); $B_{13}= q_{1D}$ (drought benefits beck flow into canal); $B_{14} = q_{1E}$ (ecological value beck water in canal); $B_{15}= q_{1clean}$ (clean beck & canal). Difference *D=￡125k* costs C1 (w. CSO) - (B2+FP3). When we are <u>willing to assign</u> combined benefits $\sum_{k=2}^{N_1} B_{1k}$*>D* over 50yrs, scenario **C1** becomes best: *break-even* 2.5k p/a.

## Info-gap theory values NBS co-benefits!

***Info-gap decision theory*** (Ben-Haim [5]) consists of three components:
(i) Costs $\tilde{U}_1 = C_1 + p_1 q_{p_1} + \alpha_{11} q_{1CSO} - \alpha_1 B_1, \tilde{U}_2 = C_2 + p_2 q_{p_2} + p_3 q_{p_3}$ benefits combined into $B_1$, $\alpha_{11}$=1; $\alpha_1$=1, i.e., system's model for scenarios C1 and B2+FP3.
(ii) Performance requirements $m_i(h) < C_s$ , costs & uncertainty models $I_1(h)$, $I_2(h)$ for C1, B2+FP3:

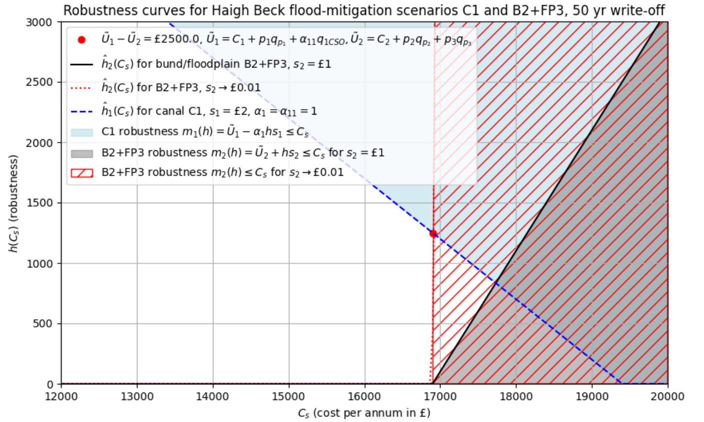
$$m_1(h) = \tilde{U}_1 - \alpha_1 h s_1 \le C_s, \quad \tilde{U}_1 = C_1 + p_1 q_{p_1} + \alpha_{11} q_{1CSO}$$

$$m_2(2) = \tilde{U}_2 + h s_2 \le C_s, \quad \tilde{U}_2 = C_2 + p_2 q_{p_2} + p_3 q_{p_3}$$

$$I_1(h) = \frac{|B_1|}{s_1} \le h, \quad I_2(h) = \frac{|U_2 - \tilde{U}_2|}{s_2} \le h$$

Hence: $h = \dfrac{(\tilde{U}_1 - C_s)}{\alpha_1 s_1} \ge 0, \quad h = \dfrac{(C_s - \tilde{U}_2)}{s_2} \ge 0$ (see graph below).

(iii) Performance aspiration or opportuneness [5,6] $\tilde{U}_2 - \beta s_2 \le C_w, \tilde{U}_1 + \alpha_1 \beta s_1 \le C_w$.




***Discussion:*** C1 has factually ***unvalued*** (natural/other) co-benefits but base costs > B2+FP3 (starting point of lines at h=0). C1 can be more robust than B2+FP3. For well-known costs of B2+FP3, such that $s_2 \to 0$, red dot at cross-over sets value of 2500p/a, ***quantifying co-benefits***. Decision-makers decide whether worth money for the extra co-benefits.
**Question**: Info-gap th. vs. Bayesian analysis? **Outcome [6]**: NBS benefits valued!


References

[1] Bokhove, Kent, Kelmanson, Piton, Tacnet 2020: *Water* **12**. https://doi.org/10.3390/w12030652
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[3] Bokhove 2024: LMS recorded talk (tool catches errors): https://www.youtube.com/watch?v=RKVoV3y5ImE
[4] Knotters, Bokhove, Lamb, Poortvliet 2024: *Cambridge Prisms: Water* **2:e6**. https://doi.org/10.1017/wat.2024.4
[5] Ben-Haim 2019: Info-Gap Decision Theory (IG). In: Decision making under deep uncertainty. https://doi.org/10.1017/wat.2024.4
[6] Bokhove 2025: Info-gap assessment. Slides: https://obokhove.github.io/EGUBokhoveVienna2025.pdf