Wetropolis flood and drought simulator

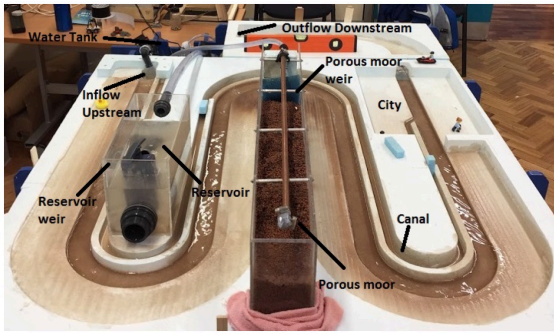
Onno Bokhove, LIFD, Leeds Institute for Fluid Dynamics, Leeds, UK

Mathematics of extreme rainfall/flood demonstrator

Wetropolis interactive flood demonstrator is based on a mathematical design and visualises how extreme rainfall events can cause extreme river-flood events in a dynamic, conceptual, portable & scaled table-top set-up. Galton boards are used to model different rainfall scenarios over the course of a Wetropolis day of wd=10seconds that can cause extreme flooding in a city, as in the real world [1].

Overview: modelled after Leeds' Boxing Day flood 2015 (with a 1:250yr **return-period** event or Annual Event Probability of **AEP**=0.4%):

- 1:100 sloped river bed; upstream inflow; with canal, reservoir/lake & porous groundwater moor draining into the river;
- chance of rare flood event in city after 90% rainfall (9s/wd) is (1/16)x(7/16)=7/256 with a *(256/7)x10s=6:06min return period*.



Galton boards: steel balls travel down and land in 1 of 4 columns with at each junction a 50% chance of ball going left or right. Galton boards randomly determine: (i) rainfall amount (columns left: 1s, 2s, 4s, or 9s) and (ii) rainfall location (columns right: lake/reservoir, moor & reservoir, moor, or no rainfall). Probability asymmetric Galton board: (3,7,5,1)/16.

Wetropolis is designed to ***flood*** under extreme rainfall (9s/wd) in moor & reservoir; two consecutive wd's of extreme rainfall lead to a chance of $(7/256)^2$ <1%; cf. Boxing-Day flood 2015.
See: https://youtube.com/watch?v=N4Sp5gHXcz4

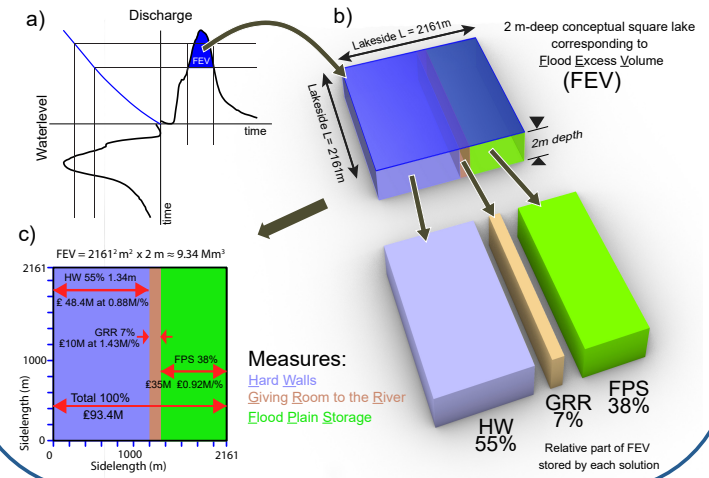
Droughts (tentative): to visualise drought for the 1/16th route of a dry day, we can use the outcome of the first Galton board (not used in absence of rainfall) after 2 pins with (3,1)/4 probability. For the 1/4-case, we enforce drought for 4 days, visualised by a drink-water pipe from the moor falling dry: *no water supply*! New probabilities then adjust to: (12,28,20,3,4)/67 for rainfall in reservoir, moor & reservoir, moor, no rain on single day & no rain for 4 days.
Drought return period: 67x10s=11:10min
New flooding return period: (16x67/28)x10s=6:23min.

Showcased across UK & spin-off

Over 1000 people experienced return periods (or AEPs) for an extreme flood by viewing Wetropolis [1] in action, e.g.:

- ***General Assembly of Maths Foresees EPSRC network*** Living with Environmental Change (LWEC), Edinburgh 2016
- ***Leeds' Armley Museum*** Public exhibition on Boxing Day 2015 floods 2016/2017
- ***Public flood conference by the Churchtown flood action group***, mathematics of extreme events, for circa 140 flood victims plus flood experts 2017
- ***Mathematics of Planet Earth Exhibition*** Wetropolis II, Imperial College 2020

Spin-off research "graphical cost-effectiveness diagnostic for policy makers"
Used in EU -France and Slovenia [2,3,4]; inconvenient truths: Natural Flood Management (NFM) flood-mitigation measures tend to have a small effect; flood-mitigation potential of beavers even minute [4], despite hype (media & scientific) statements.



References
[1] Bokhove, Hicks, Kent, Zweers 2020: *Hydrology and Earth System Sciences* 24
Design: https://github.com/obokhove/wetropolis20162020
[2] Bokhove , Kent, Kelmanson, Piton, Tacnet 2019: *River Research Applications* 35
[3] Bokhove , Kent, Kelmanson, Piton, Tacnet 2020: *Water* 12
[4] Bokhove, Kelmanson, Kent Hicks 2021: REF2021 impact case study.
UK Gov Inquiry: https://committees.parliament.uk/writtenevidence/9641/pdf/
NEXT: Employ Wetropolis as scientific experiment on risk-based modelling of climate change.