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MUSE GeoERA — Managing Urban Shallow Geothermal Energy

Groundwater modelling with Modflow 6 to support heat recovery from a shallow urban aquifer

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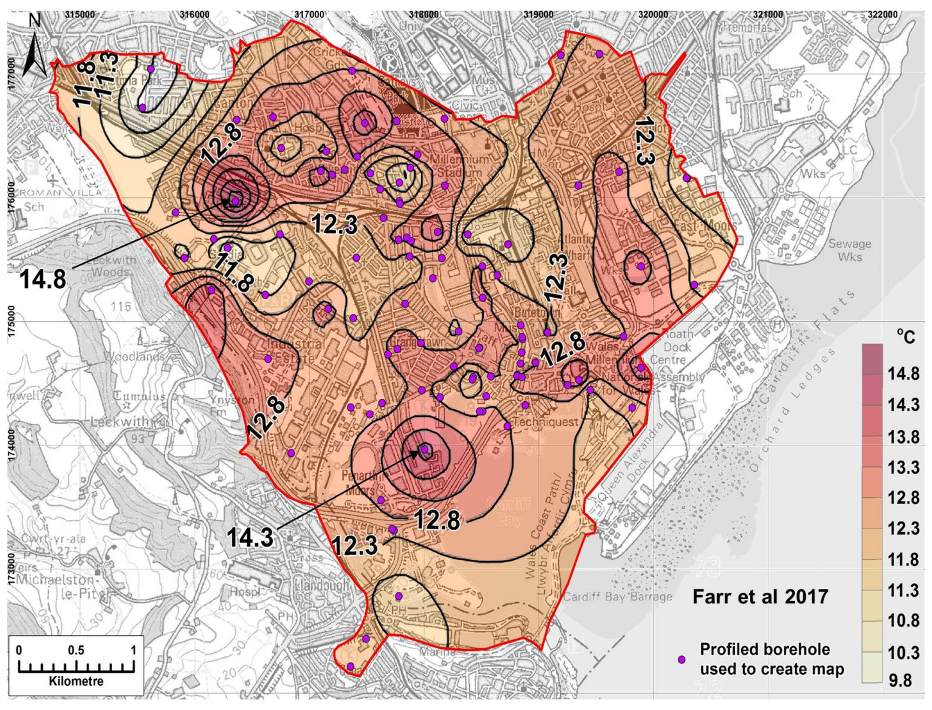
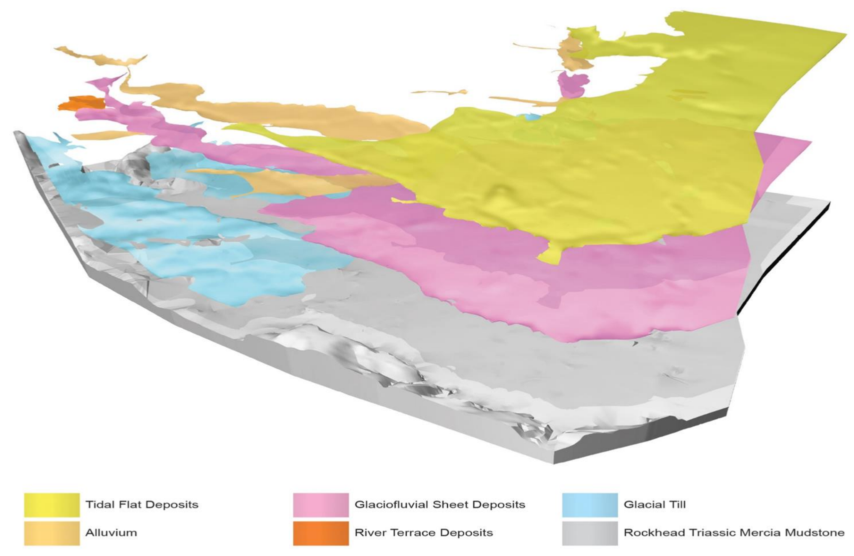
Introduction

- If we are to achieve targets to reduce greenhouse gas emissions then low-enthalpy ground source heating may provide a secure and low carbon form of space heating.
- The measured shallow groundwater temperatures under the City of Cardiff were found to be 2°C warmer than predicted, attributed to the subsurface urban heat island effect.
- For geothermal resource mapping and regulation, heat advection and the urban groundwater flow system need to be understood.
- Here, we develop a groundwater and recharge model of the shallow aquifer in Cardiff.



Study setting

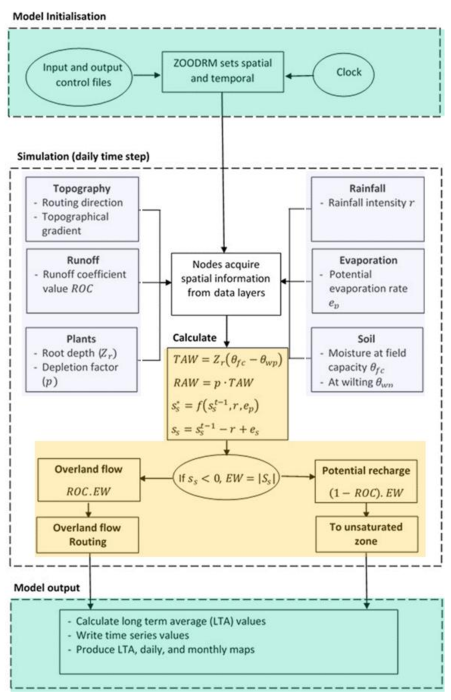
Cardiff is located on a flat coastal plain adjacent to the Bristol Channel. Following the construction of the Cardiff Bay Barrage in 1999, mud flats with a tidal range of ~10 m were turned in to a freshwater lake at a fixed elevation of 4.5 m a.o.D. The city is underlain by Triassic Mercia Mudstone, which is overlain by Quaternary superficial deposits, and consists of the sand and gravel aquifer of gaciofluvial origin, and lower permeability confining units, the tidal flat deposits. From before the construction of the Cardiff Bay Barrage, an extensive groundwater monitoring network was set in place, of which 194 boreholes are still monitored by Cardiff Harbour Authority. This well instrumented urban environment provides the opportunity to help understanding urban groundwater flow system, with recharge and discharge from urban infrastructure, rivers, docks, the Cardiff Bay barrage and the sea.



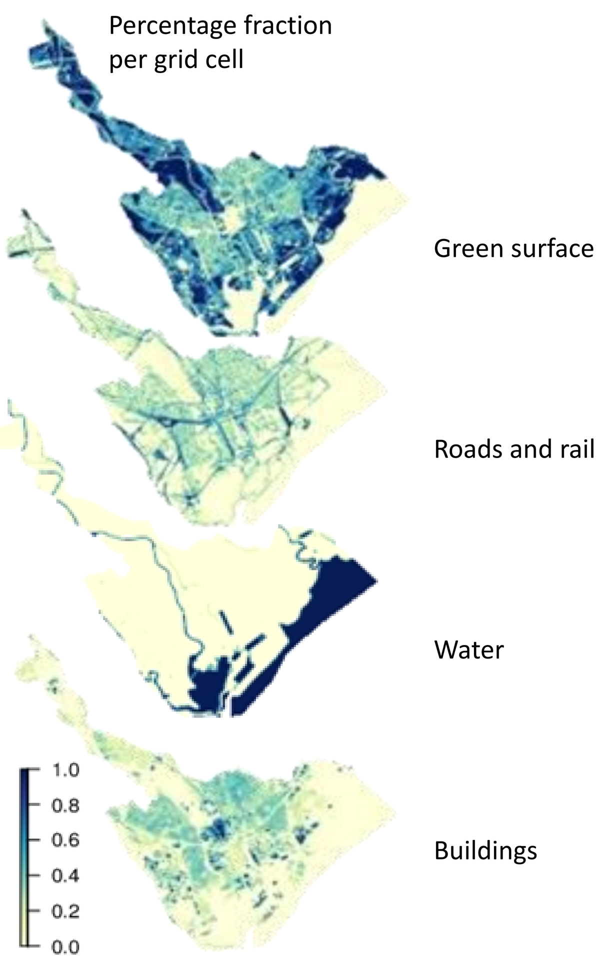
Kendall et al 2019

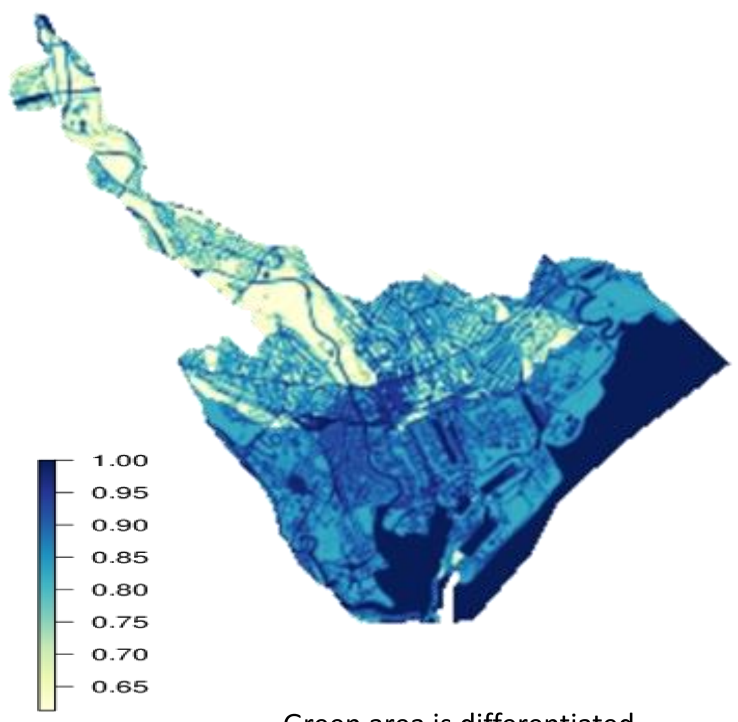
Recharge modelling for Cardiff

- Zooming Object Oriented Distributed Recharge Model (ZOODRM) developed by Mansour and Hughes, 2004.
- ZOODRM has been applied to estimated distributed potential recharge for the UK (Mansour et al, 2018).
- Model drivers and states: rainfall, evaporation, land use, soil characteristics, topography and geology.
- ZOODRM calculates recharge and runoff.
- Runoff is routed downstream until it reaches a river node.



Derivation of runoff coefficient using percentage land cover aggregated to model grid and host soil map

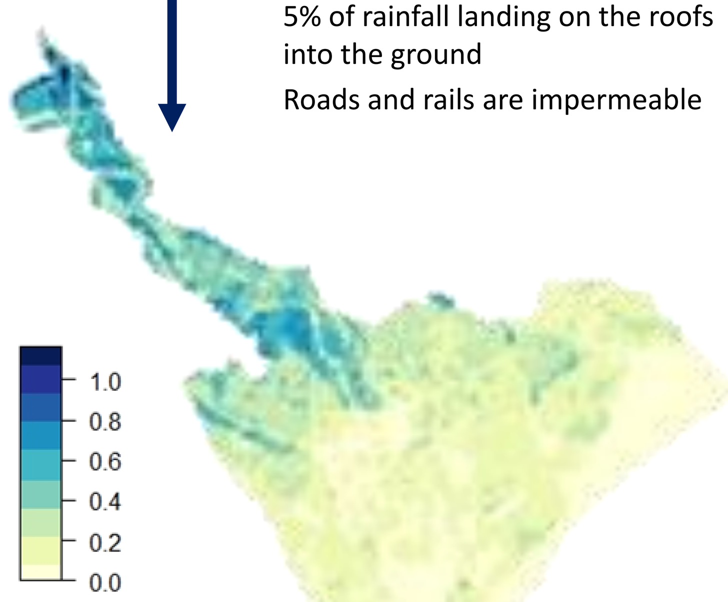




Green area is differentiated whether it overlies the tidal flat deposits and alluvium

Buildings are assumed to direct 5% of rainfall landing on the roofs into the ground

Roads and rails are impermeable



Modelled distributed long term average recharge

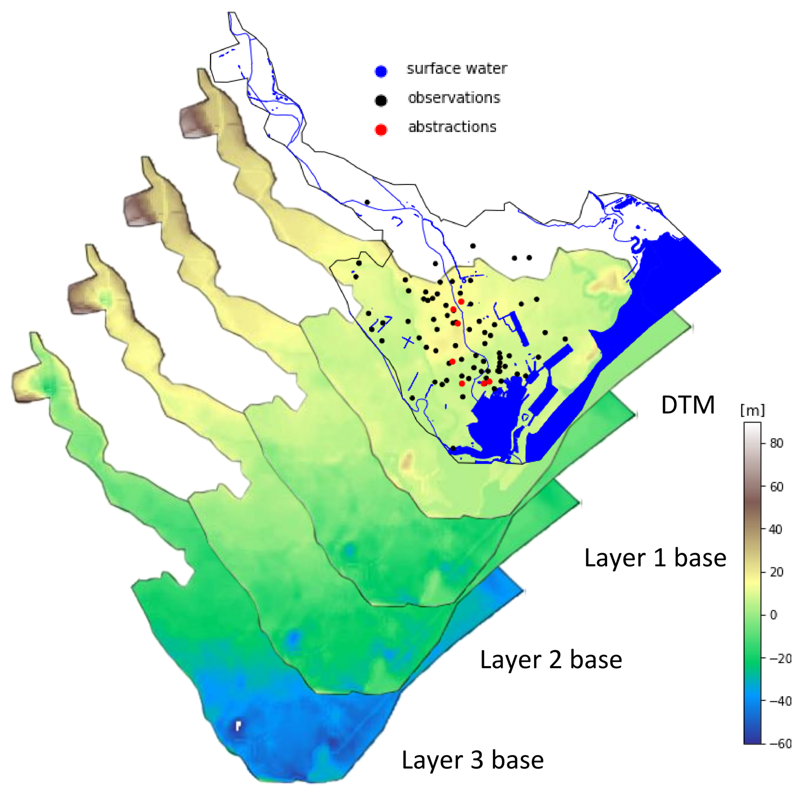
- For UK wide model Host soil map is used at 1 km
- How to represent urban, built up areas?
    1) estimation of built-up area, green area and % of roofs draining into the ground
    2) Built-up area and green area derived from 1:5000 OS map
- Aggregated to 5 classes

Groundwater modelling

- Use of Modflow 6, FloPy and Gridgen

3 layers:
1) Tidal flat deposits, river alluvium or glacio-fluvial depoisits
2) Glacio-fluvial deposits
3) Mercia Mudstone

- Interaction with rivers, coast, barrage, docks and other surface water
- Groundwater control systems after barrage construction
- Extensive monitoring network
- Additional recharge flux scaled to mains network length per grid cell
- Loss into sewers



Mains network length mapped onto model grid (©DCWW)

Water infrastructure network obscured for confidentiality reasons

Sewer network length mapped onto model grid (©DCWW)

Water infrastructure network obscured for confidentiality reasons