

Mapping suitability for low enthalpy heating/cooling technologies in Scottish superficial aquifers

1) Context

- Heating, particularly spatial heating, is the single largest source of carbon emissions in the UK.
- Vast majority of spatial heating in the UK is met using gas boilers.
- Strategy to meet 2019 commitments to net zero economy by 2050 address the need for decarbonised heating, partially by commitment to 600,000 GSHP installations per year by 2028¹.
- Is there a suitable resource in Scotland to support this?

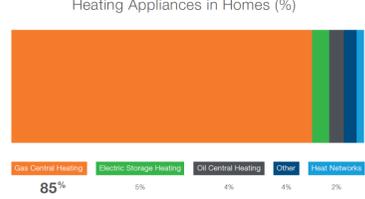
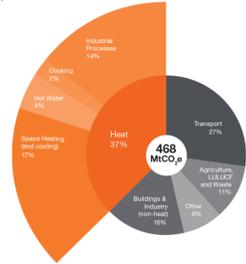


Fig 1.1 Left: Space heating appliances in homes in 2016¹.
Fig 1.2 Right: UK emissions in 2016 across different sectors¹.



2) Aims

- Do superficial groundwaters have the potential to contribute to heating/cooling decarbonisation in Scotland?
- Identify and combine key criteria.
- Produce a metric by which criteria may quantitatively be compared.
- Produce a metric that can observe data confidence.
- Provide a national scale GSHP screening tool for Scotland that can be used to gain a generalised knowledge of subsurface suitability.
- Provide a tool for site selection to advance PhD project.

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Criterion	Dataset	Favourability Index (FI: 0-5)				
		1 Unfavourable	2 Questionable	3 Neutral or No Data	4 Encouraging	5 Favourable
Geological Parameters						
Superficial Coverage	BGS Geology 625k (Superficial)	No known deposits	N/A	Deposits present, No information	N/A	Known deposits exist continuously
Deposit Thickness	BGS National Superficial Deposit Thickness Model (Basic)	>1-5m	>5-10m	0-1m (See STDM guide, Deposits of unproven thickness given value of 1m)	>10-15m	>15m
	BGS Buried Valleys (Onshore)	Not Present	N/A	N/A	10-20m	20-30m, 30-40m, greater than 40m
Superficial Aquifer Productivity	BGS Hydrogeological Mpas of Scotland	No aquifer/NSA (Not a significant aquifer)	ILM (Intergranular flow, low-moderate productivity: 0.1 - 10 l/s)	Unknown geology	Aquifer present. IMH (Intergranular flow, moderate to high productivity: 1 - 10 l/s)	Aquifer present. IH (Intergranular flow, high productivity: >10 l/s)
	BGS Susceptibility to groundwater flooding	Not considered prone to flooding	Limited Potential for groundwater flooding	N/A	Potential for groundwater flooding in sub-level structures	Potential for groundwater flooding at surface
Groundwater Parameters						
Temperature	Met Office: HADUK-Grid	1-3C	>3-4.5C	>4.5-6C / no information	>6-7.5C	>7.5C
Chemistry	BGS Civils: Sulfate/Sulfide potential	7 (mapped water-N/A); 1 (Primary calcium sulfate present)	2,3	6	4,5	0 (Primary sulfate not present)
	BGS Civils: Corrosivity (ferrous)	>11	N/A	9 to 11	N/A	<9
Non-geological Parameters						
Heat demand	Scottish Government: Scotland Heat Map (Kwh/yr)	372-5,000; & no data	5,000 -20,000	20,000 - 2 x 10 ⁷	2 x 10 ⁷ - 1.8 x 10 ⁸	1.8 x 10 ⁸ - 1.355 x 10 ⁹
Protected areas	Scottish Government: SpatialData.gov.scot	Very sensitive ecological, environmental or cultural features, posing significant barriers gaining GSHP permissions.	Land may have several protections/restrictions or sensitive features that will negatively impact potential GSHP installation	Land may be within protected regions with mild impacts on GSHP installation	Land may be within protected regions but has no impact on GSHP installation	No restrictions / environmental protection on land use beyond private permissions

3) Methods

a: Producing a Favourability Index (FI:0-5)

- Identify key criteria essential to effective GSHP operation.
- Identify existing datasets that quantify these criteria.
- Recategorise these data on a common scale of GSHP favourability to allow comparison.

b: Stacking inputs

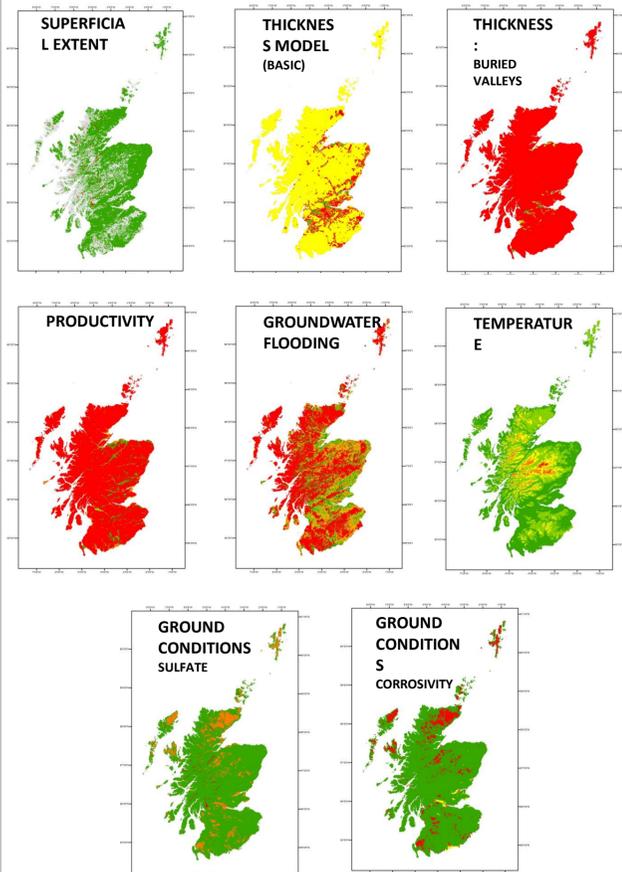
- 10 input datasets used, converted to the same raster format: 1km grid. British National Grid, D_OSGB_1936, cell assignment by maximum area, no priority.
- Cumulative FI scores from multiple inputs over the same unit area can be averaged to produce a 'favourability index' specific to that unit area.

c: Observing data confidence

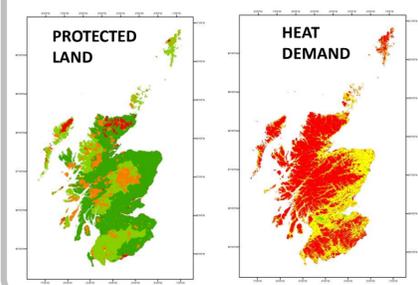
- Data confidence and reliability scored (0-5) for a variety of epistemic and aleatory uncertainties, and biases.
- Each unit area receives a data confidence value that is the average of its uncertainty and bias scores across datasets.

Fig 2.1 Left: Favourability Index 'scoring' table, showing input data conversion to FI values. **Fig 2.2 Right:** Input dataset map tiles, recategorised by FI.

BELOW GROUND FACTORS



ABOVE GROUND FACTORS



4) Results

Fig 3.1:

Superficial deposit GSHP favourability map of Scotland, including above and below ground factors. Deposits range FI: 3.2, mean FI: 3.3, max 4.9, with 2,214km² identified as high suitability (FI≥4).

Fig 3.2:

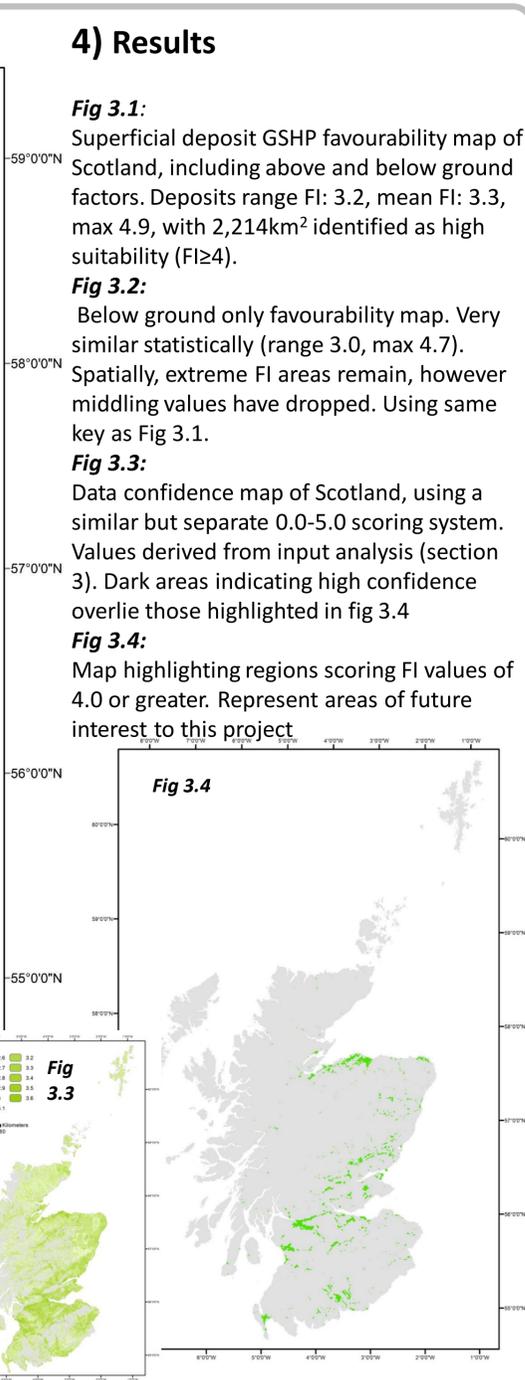
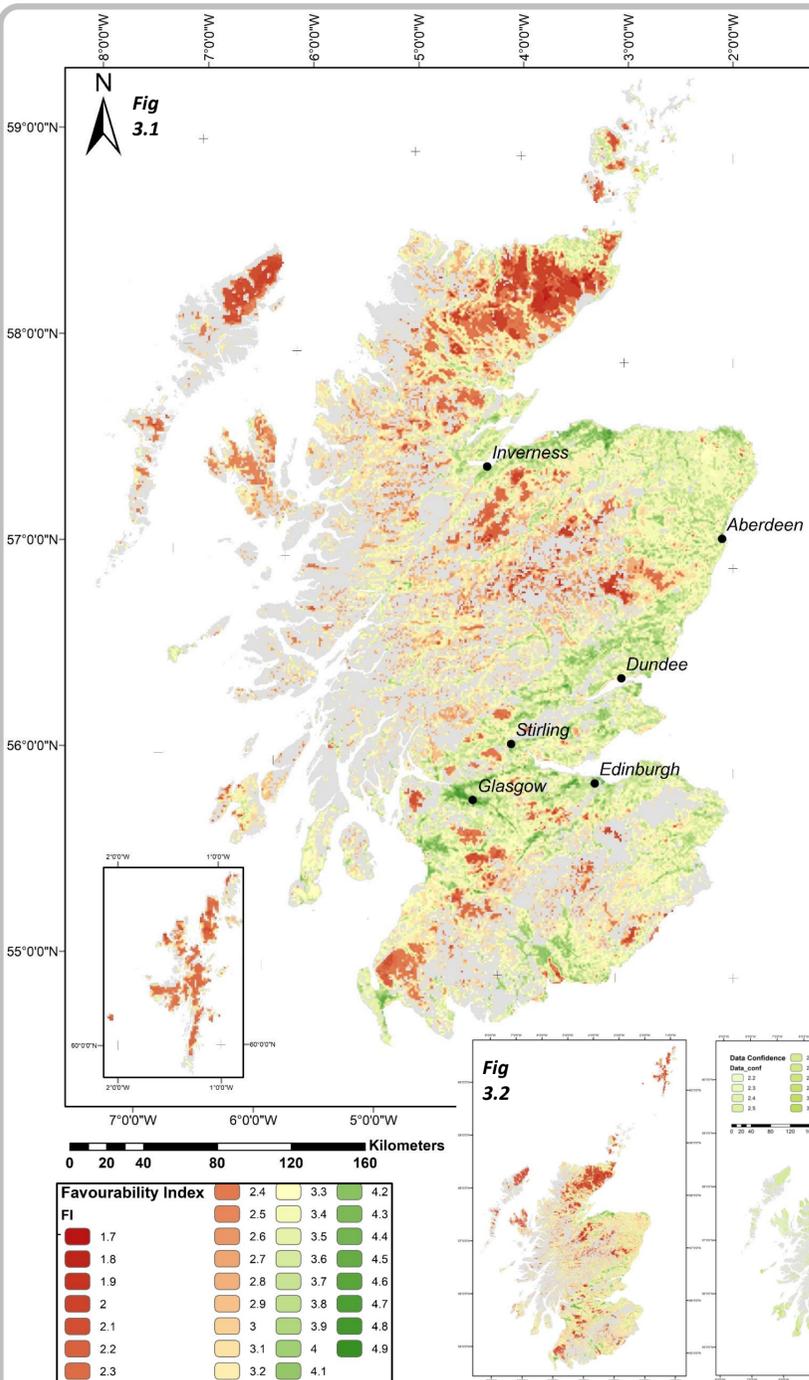
Below ground only favourability map. Very similar statistically (range 3.0, max 4.7). Spatially, extreme FI areas remain, however middling values have dropped. Using same key as Fig 3.1.

Fig 3.3:

Data confidence map of Scotland, using a similar but separate 0.0-5.0 scoring system. Values derived from input analysis (section 3). Dark areas indicating high confidence overlie those highlighted in fig 3.4

Fig 3.4:

Map highlighting regions scoring FI values of 4.0 or greater. Represent areas of future interest to this project



5) Conclusions

- Highest favourability areas coincide with population centres even without considering above ground (human) factors. 2011 census data shows approx. 25% of Scottish population (1.3 million) live in an area with an FI value of 4 or greater, suggesting GSHPs in superficial aquifers do represent a significant resource for future decarbonisation of heating/cooling demand.
- Specific sites may now be targeted within this high FI region for specialised assessment.
- Screening tool shows superficial sourced groundwater is not a universal heating/cooling resource across Scotland, and should not be treated as such in future decarbonising targets.
- Screening tool inherits availability bias from its input datasets, and is subject to individual geoscientist FI categorisation bias.