

# Potential for Groundwater Heating in Cardiff

Thursday 23<sup>rd</sup> June 2016

Grangetown Nursery, Cardiff



# WELCOME

Gordon Brown, Director  
Constructing Excellence in Wales



Innovate UK

# Groundwater

## as a Sustainable Energy Resource

**Gareth Harcombe**

Energy and Sustainability Manager

City of Cardiff Council

**difference** | **wahaniaeth**  
make the | gwnewch



# Cardiff Council



## Background and Scene Setting

- Cardiff's Energy and Sustainability Agenda
- Overview of live projects
- Introduction to the Groundwater project



# Strategy



Energy

Waste

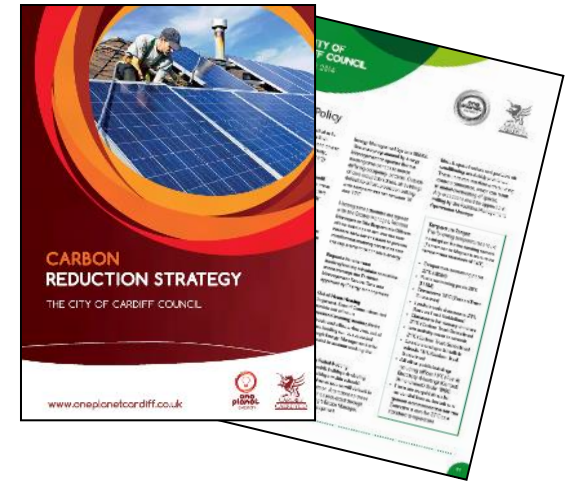
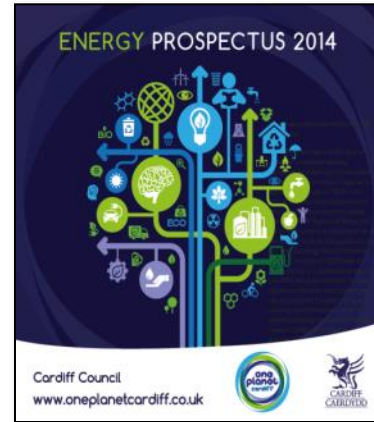
Transport

Food

Water

Place

People



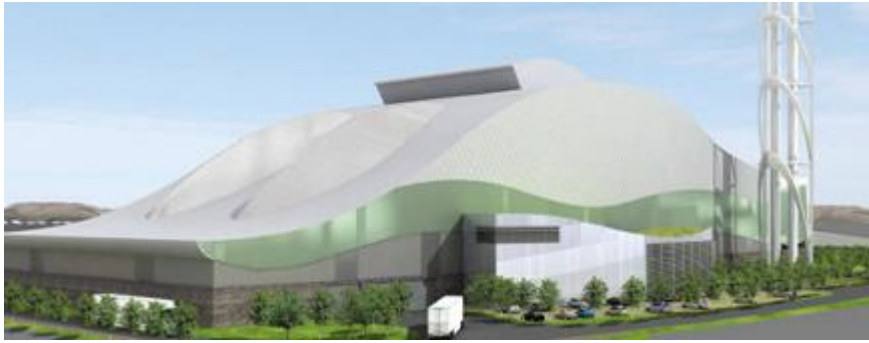
Increasing, diversifying and localising supply

Reducing demand

# Partnership Schemes



## Trident Park Energy from Waste Plant



- 30MW of electricity
- Potential for 20MW of heat?

## Anaerobic Digestion Plant



- 1.5 MW of electricity
- Heat?



## Landfill Gas Burners

- 4MW of electricity

# Council Schemes



## Radyr Weir Hydro Electricity Scheme

- 0.4MW electricity
- Anticipated Completion April 2016



## Solar

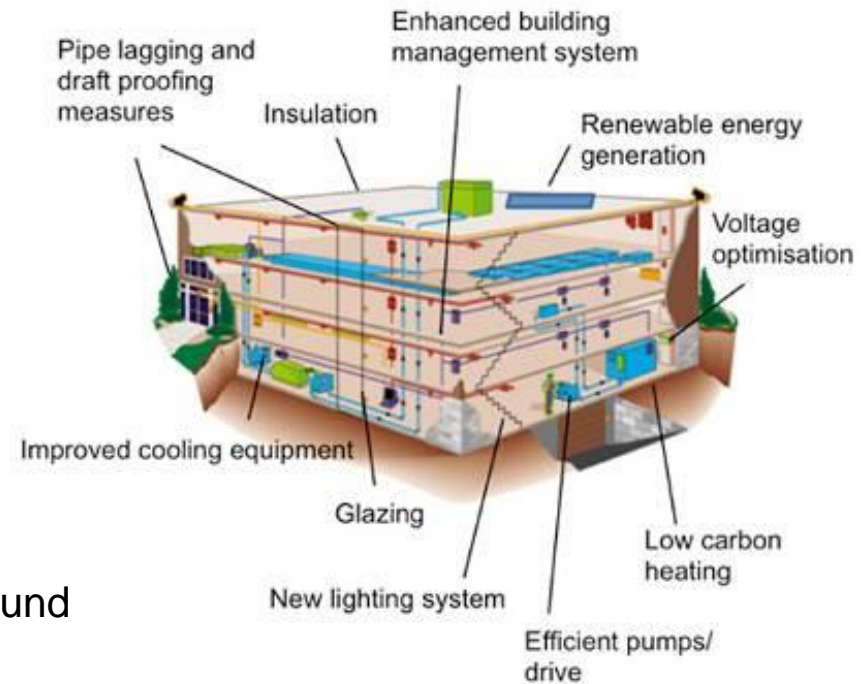
- Almost 0.5 MW roof mounted installed this financial year
- Solar Farm?? – 5-7MW



# Energy Efficiency in the Council's Estate



- \* **£10m energy cost P/A**
- \* **SALIX** - estate and street lighting
- \* **Re:Fit**
- \* Provides guaranteed energy savings
- \* Wide range of possible measures
- \* Up to £4m of works
- \* Incl £2.2m Welsh Government Invest to Save Fund
- \* In contract with Engie (Cofeley)
- \* Works start spring 2016





# INNOVATION PROJECTS

7 live projects  
£2.3m external funding  
Over 20 partner organisations

# Heritage Retrofit SBRI

## The “problem”

- More than 30% of buildings in Wales are over 100 years old
- Mainstream retrofit sometimes conflicts with heritage protection

## Response

- 30 applicants, 6 feasibility projects, 3 demonstrators



### Vivus Lime

Quick drying lime render and insulation panels

The block contains four photographs. The top-left shows a two-story brick house with a white car parked in front. The top-right shows a close-up of a stone wall with white lime render being applied. The bottom-left shows a room with floral wallpaper and a ceiling being treated with the render. The bottom-right shows a room with a white wall and a window, with a ladder leaning against it, indicating ongoing work.

### Q-Bot Limited

Underfloor Insulation Robot

The block contains two images. The top image shows a small, four-wheeled robot with two long white antennae on a wooden floor. The bottom image is a 3D architectural cross-section showing the robot positioned under a floor, installing a layer of pink insulation panels.

### Okotech Ltd Heatboss®

wireless zoned heating control solution.

The block contains two images. The top image is a screenshot of the Heatboss mobile app, showing a grid of temperature controls for different zones. The bottom image shows a hand turning a black knob on a yellow radiator, which is part of the Heatboss wireless zoned heating control system.

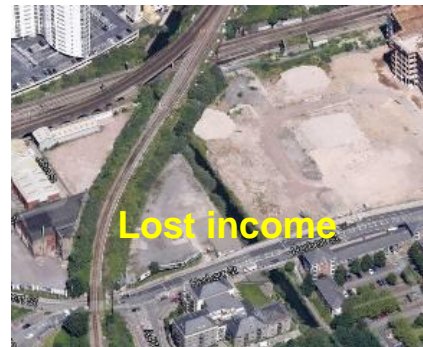
# Portable Renewables SBRI

## The “problem”

- Vacant and underused land
- Not enough renewable generation in cities
- Can energy be a temporary “meanwhile” use

## Response

- 35 applicants, 4 feasibility projects, 2 demonstrators

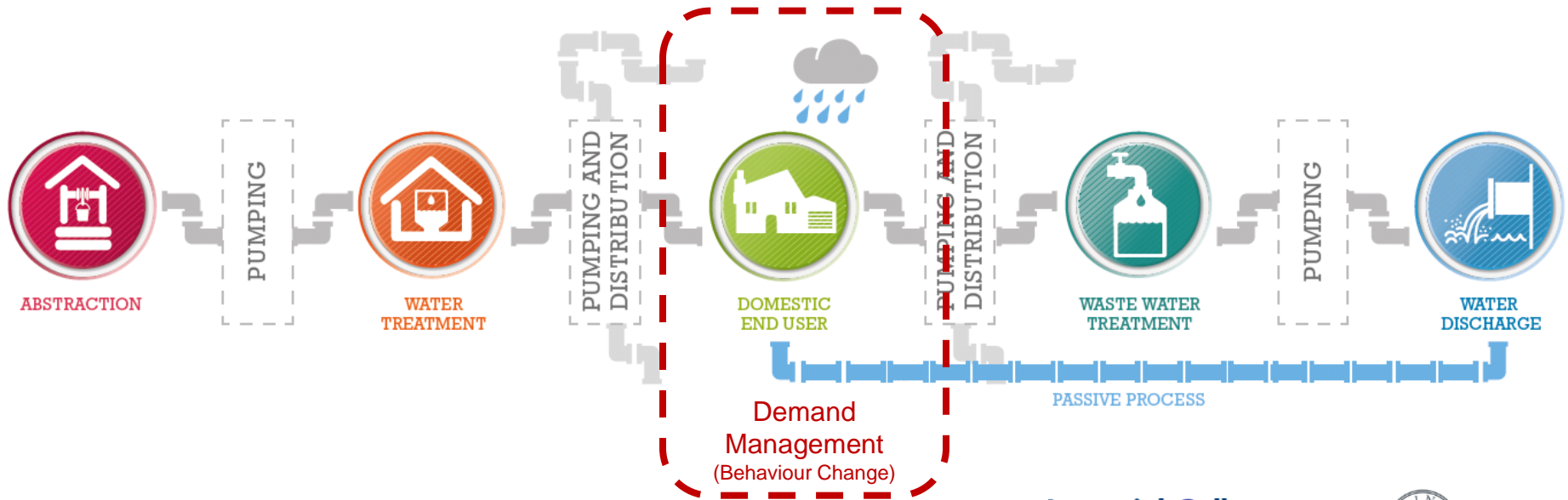


# Hydrogen Enabled Local Energy



# EU FP7 WISDOM

Water analytics and Intelligent Sensing for Demand Optimised Management



Dŵr Cymru  
Welsh Water

Imperial College  
London



**iDRAN**

ingegneria e tecnologia



CARDIFF  
UNIVERSITY  
PRIFYSGOL  
CAERDYDD



**CSTB**  
le futur en construction

advanticsys

make the difference | gwnewch  
**wahaniaeth**

# EU FP7 PERFORMER



Portable, Exhaustive, reliable, Flexible and Optimized appRoach to Monitoring and Evaluation of building eneRgy performance

- Understand why building actual energy performance is different to building predicted energy performance
- Look to reduce this gap by better management of the buildings HVAC systems through ICT controls



# Cardiff Heat Network



H.N.D.U funded feasibility work

- Heat map and masterplan
- Technical delivery study
- Planning Guidance
- Business Planning
- Legal and Governance Issues



Department  
of Energy &  
Climate Change

**H.N.D.U**

# GROUNDWATER PROJECT



**British  
Geological Survey**

NATURAL ENVIRONMENT RESEARCH COUNCIL

**Innovate UK**

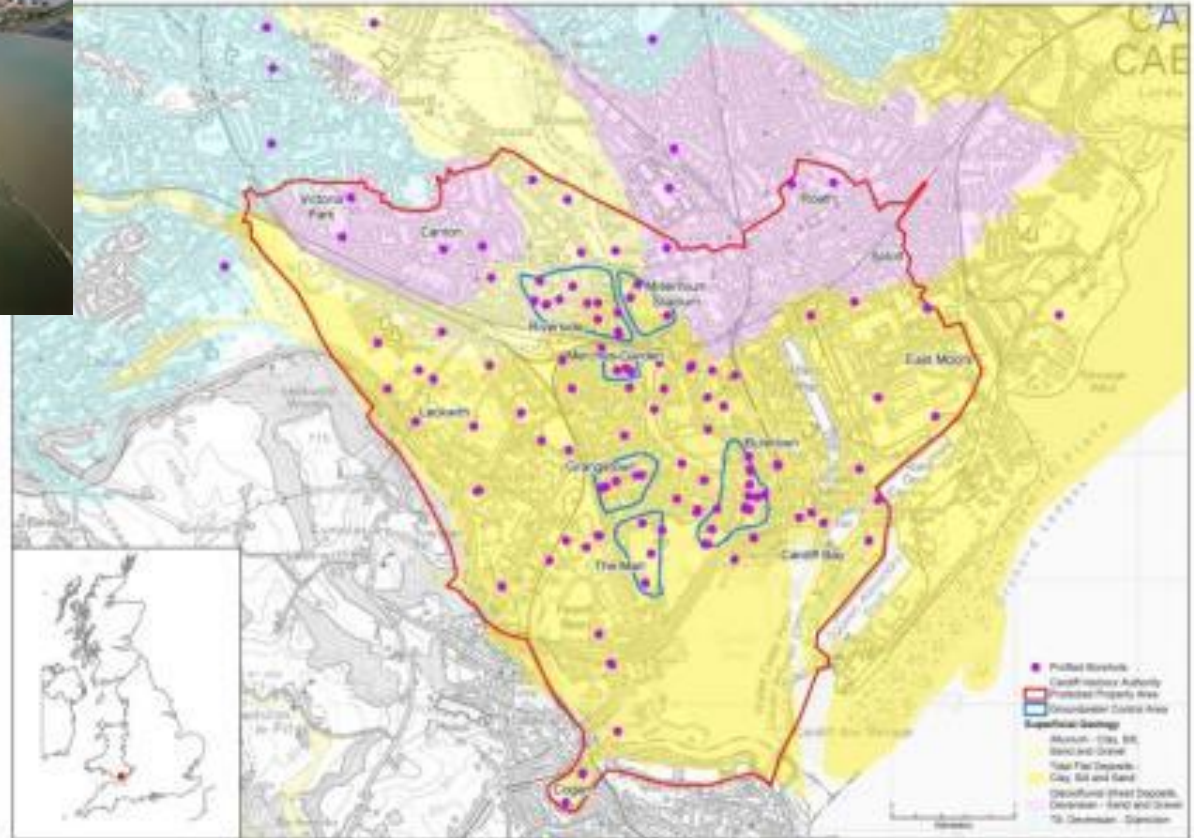
**Energy Catalyst**

**difference** make the | **wahaniaeth** gwnewch





# Cardiff Bay Barrage



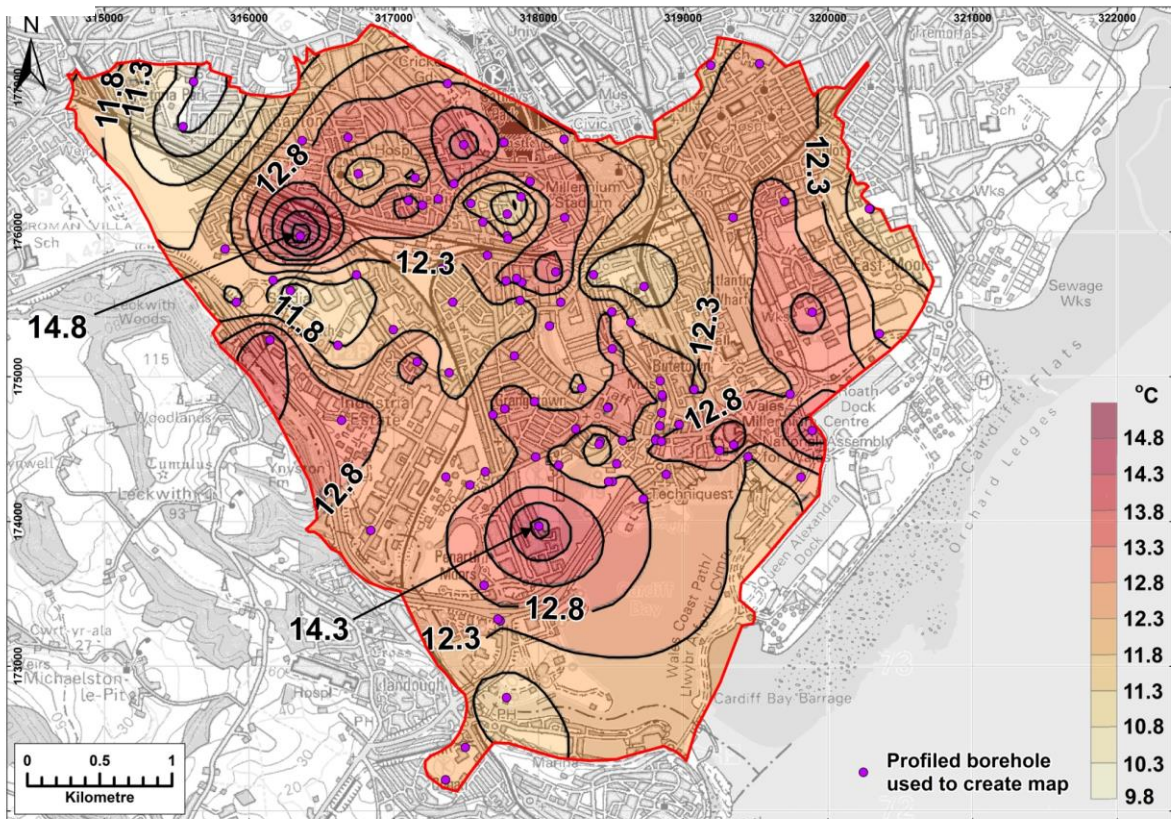


HARBOUR AUTHORITY  
AWDURDOD HARBWR



# British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL



# Questions

- Is the groundwater a viable heat source?
- Is the heat resource sustainable?
- At what scale – building/street/district/city?
- What technology?
- Stand alone or system integration?



Innovate UK

Energy Catalyst



Successful “Early Feasibility Stage” funding application

# Progress to Date



- Sensors and impact monitoring in 60 boreholes
- Grangetown Nursery School Heat pump
- 3D city scale geological mapping

**BEDROCK**

# Progress to Date



## Our energy use

For the 24 hours commencing midnight on 22 Nov, Grangetown Nursery School has used:

**20kWh**

Gas

Average 0kWh per hour

**£0**

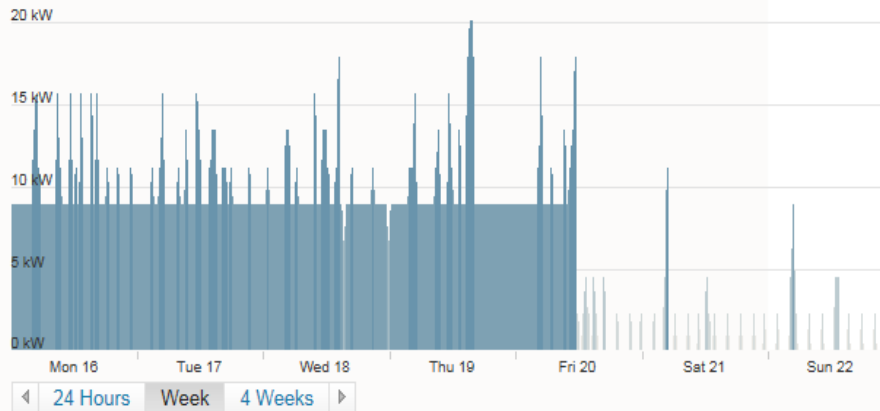
Money

Average £0 per hour

**3kg**

Carbon impact

Average 0kg per hour



This graph allows everyone to access a range of data from Grangetown Nursery School. It's updated frequently, as we receive new data from the on-site meters.



<https://platform.carbonculture.net>.



# British Geological Survey

NATURAL ENVIRONMENT RESEARCH COUNCIL



British Geological Survey  
NATURAL ENVIRONMENT RESEARCH COUNCIL  
Arolwg Daearegol Prydain  
CYNGOR YNCHWILYR ANGYLCHEDD NATUROL

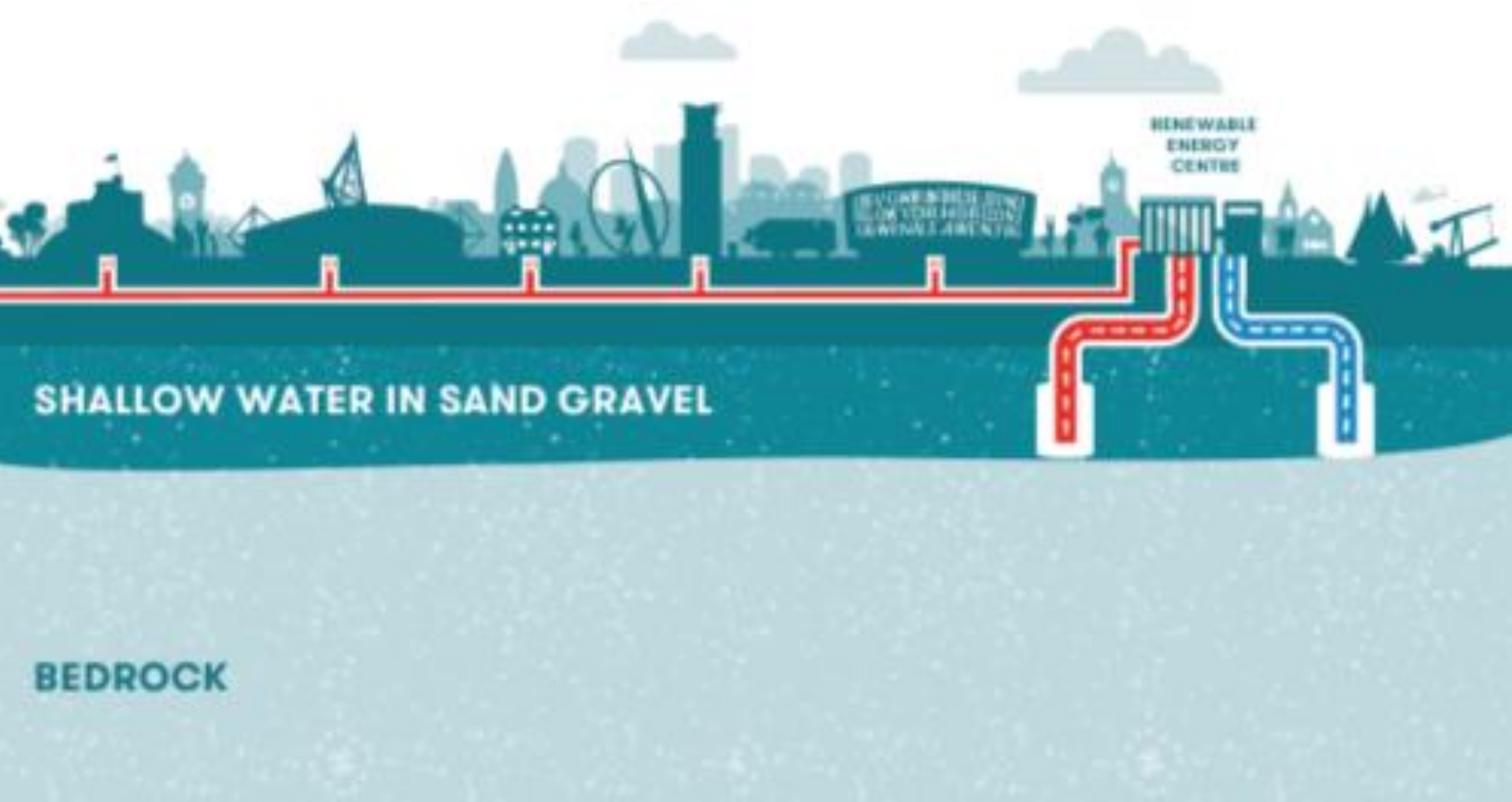


Innovate UK  
Technology Strategy Board



# Geological R&D: Feasibility Stage

- Sensor network installed and impact monitoring in 60 boreholes
- 3D city scale geological mapping and long-term heat models



# BGS Groundwater Investigations

## Drivers for research:

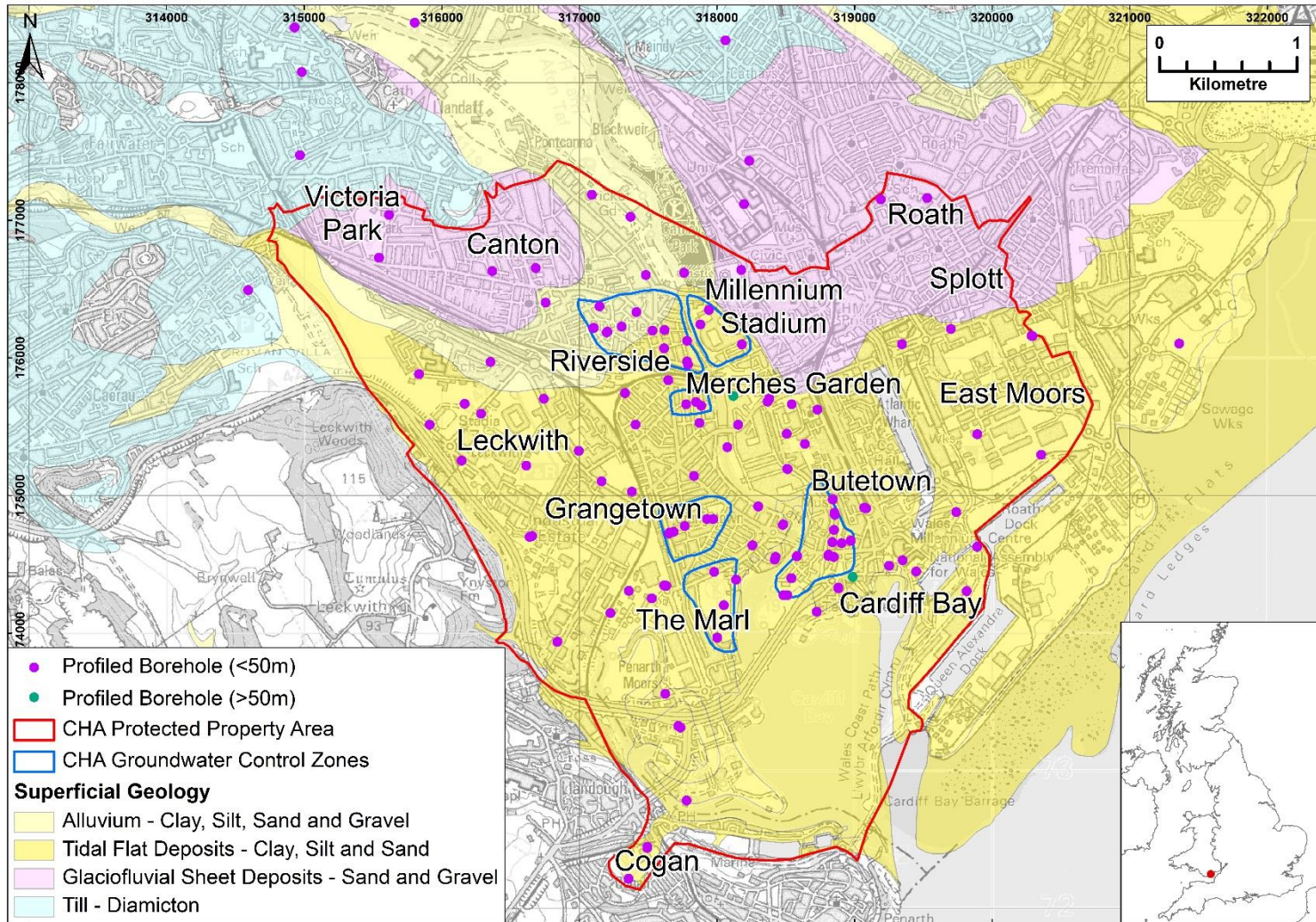
- Resource characterisation (volume, yields, temperature)
- Environmental Regulation framework (NRW)
- Need for baseline data and guarantees of performance/Insurance

## Research Questions:

- Where is there usable groundwater in the city?
- Are there seasonal temperature trends below ground?
- What is the groundwater and heat flow direction: how does pumping affect natural heat recovery and artificial recharge?
- Will Iron and Manganese oxidation be an issue?



# Cardiff Borehole Network

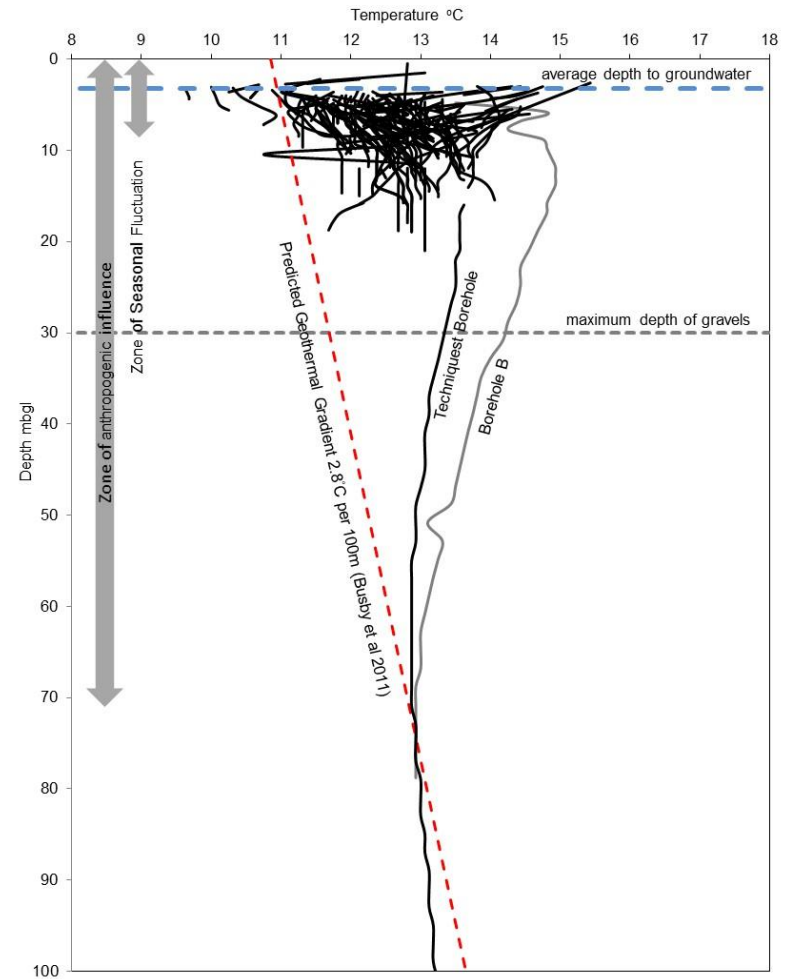


Farr et al. 2016, QJEGH (In Prep)

# Borehole Temperature Profiling

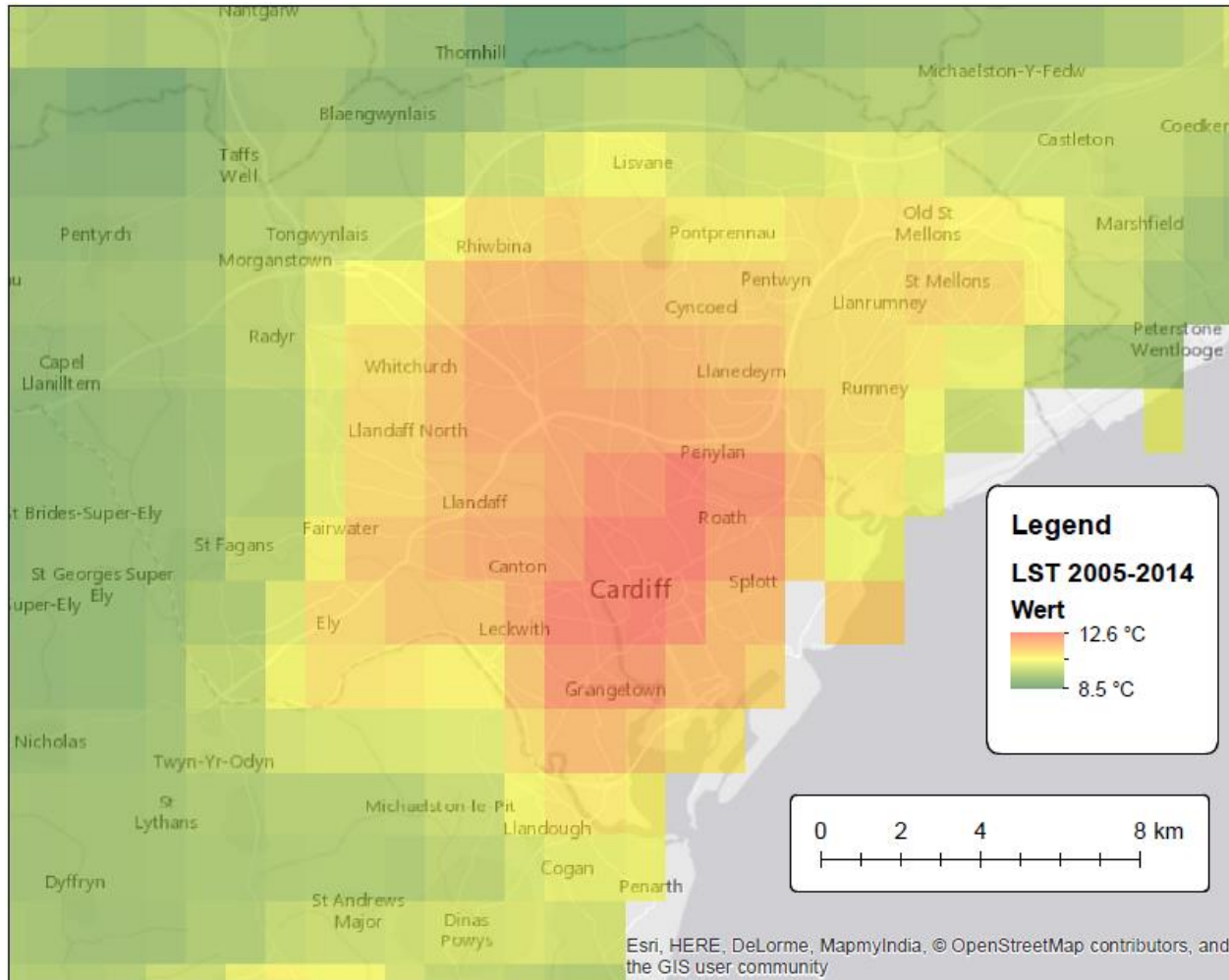


- 169 boreholes sampled
- Spring and winter 2014 & 15
- Average temperature is 12.4°C
- Temperatures were 2°C above 'expected' geothermal gradient

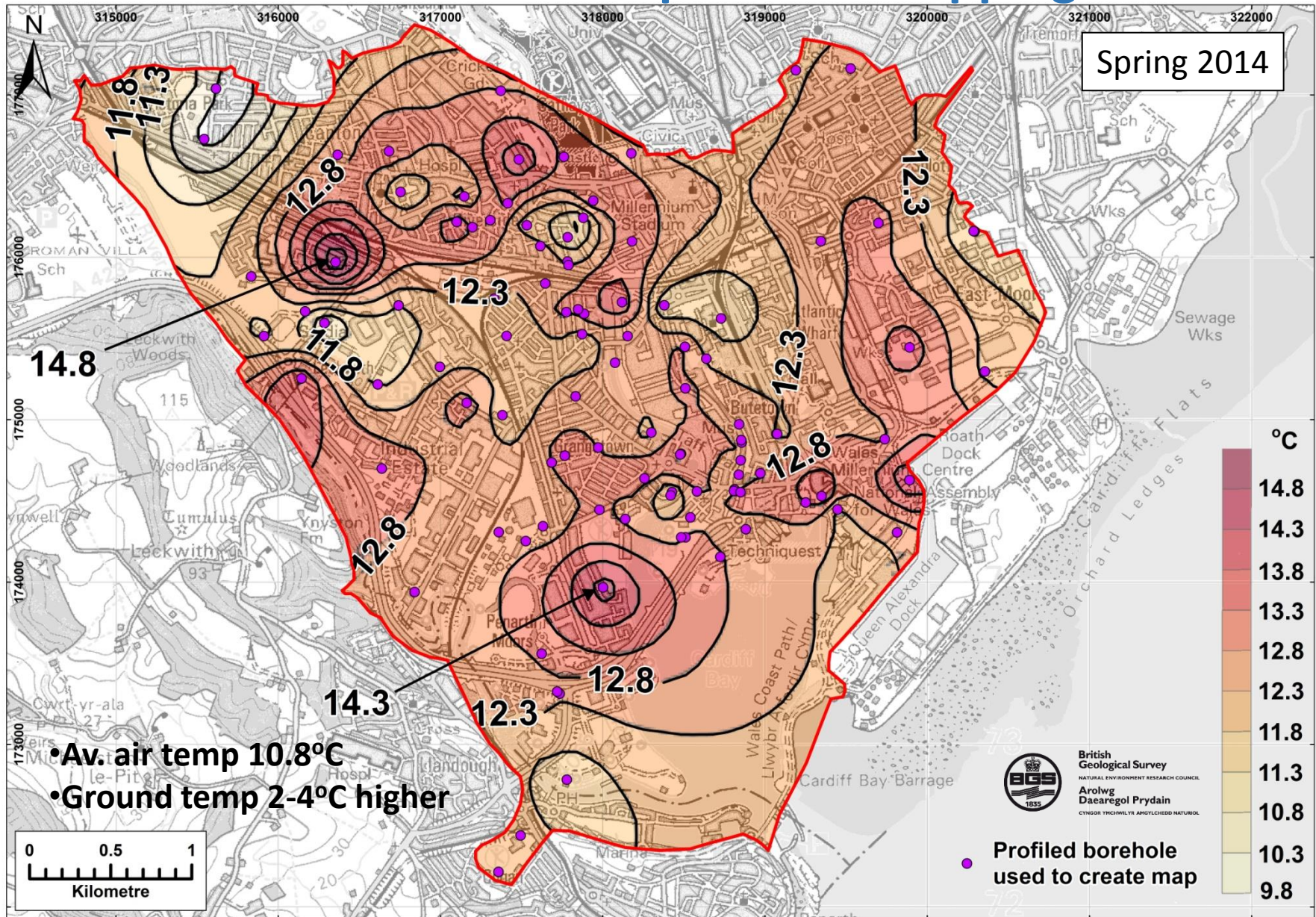


Farr et al. 2016, QJEGH (In Prep)

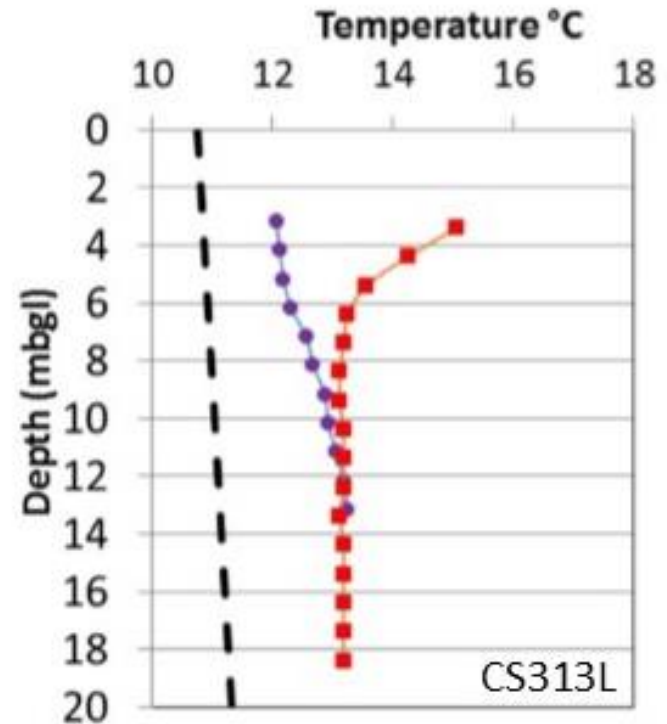
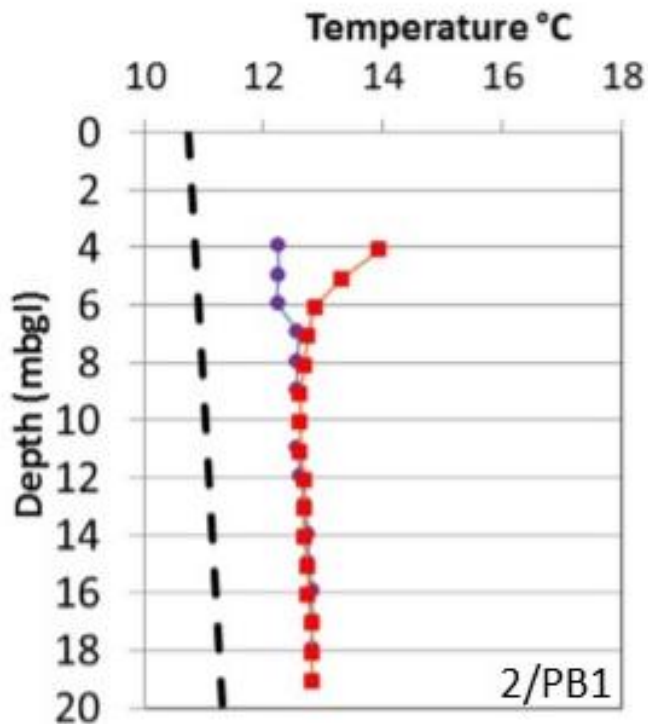
# Urban Heat Island Effect (Surface Temperature)



# Groundwater Temperature Mapping

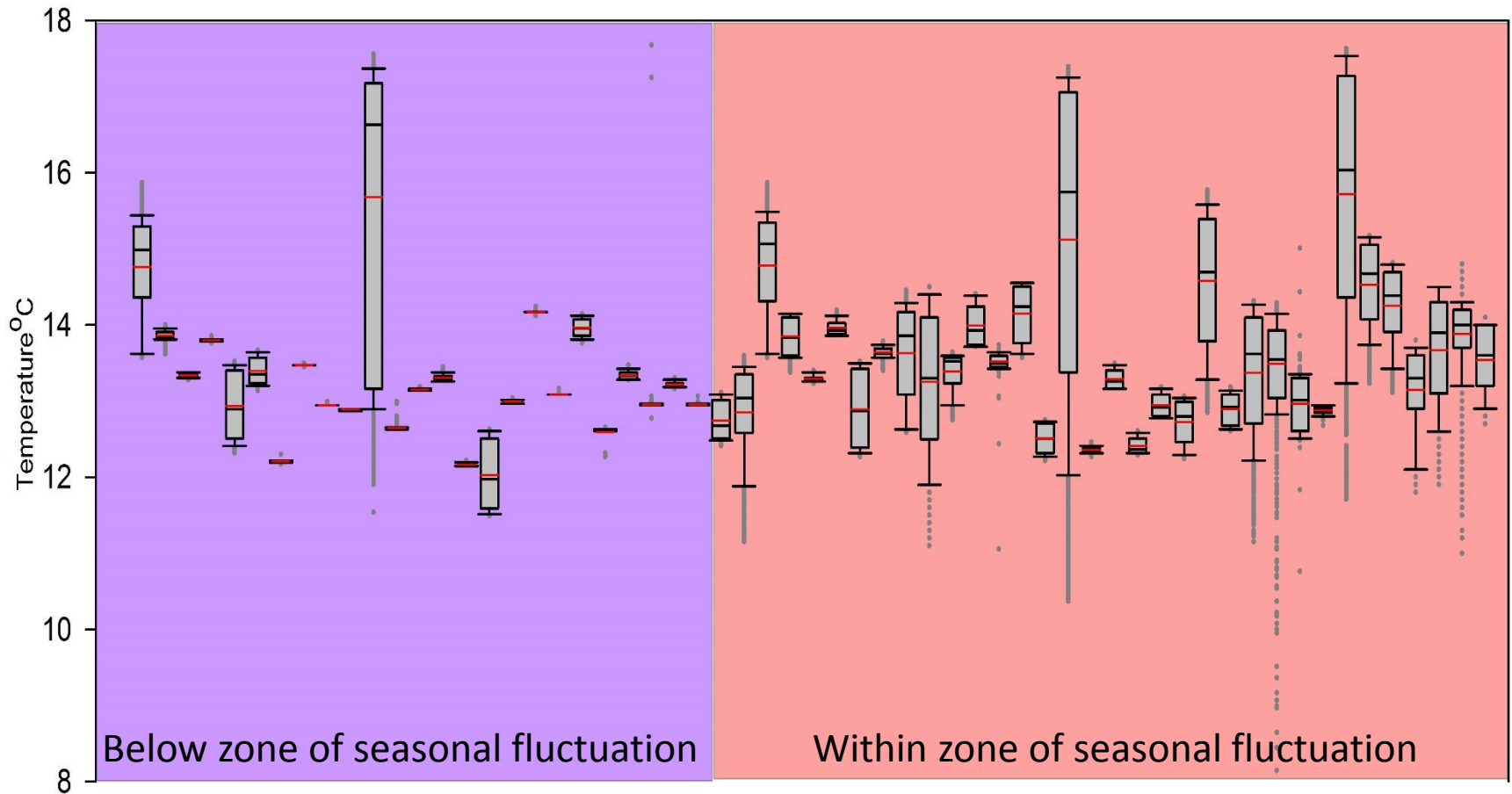


# Seasonal GW Temperature Variation Below Ground

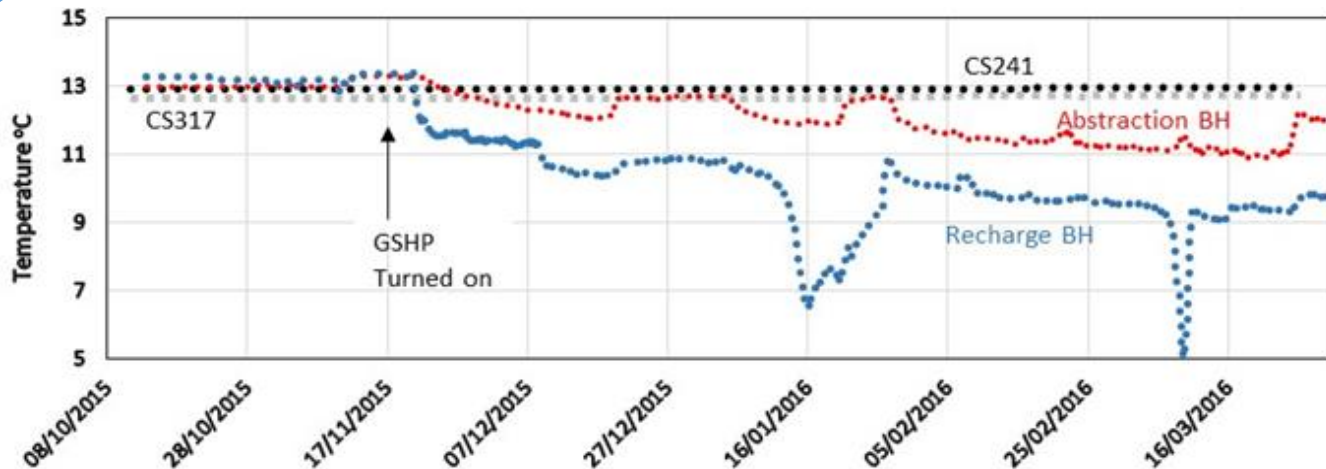
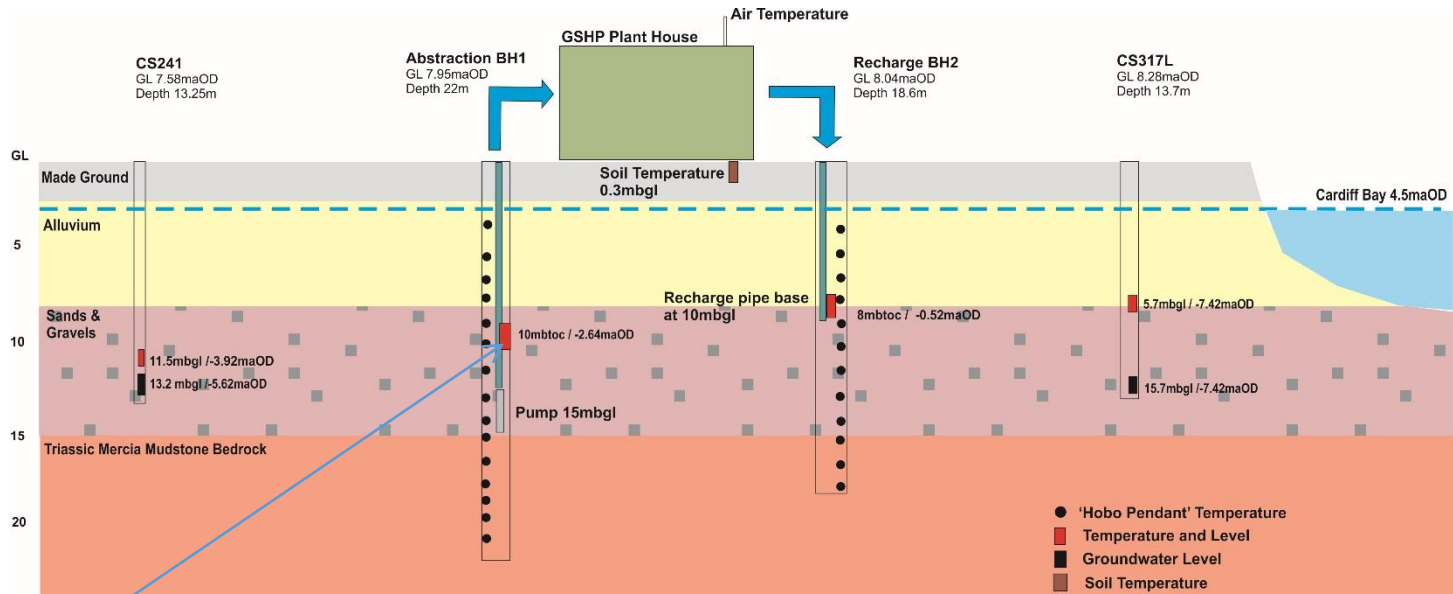


Farr et al. 2016, QJEGH (In Prep)

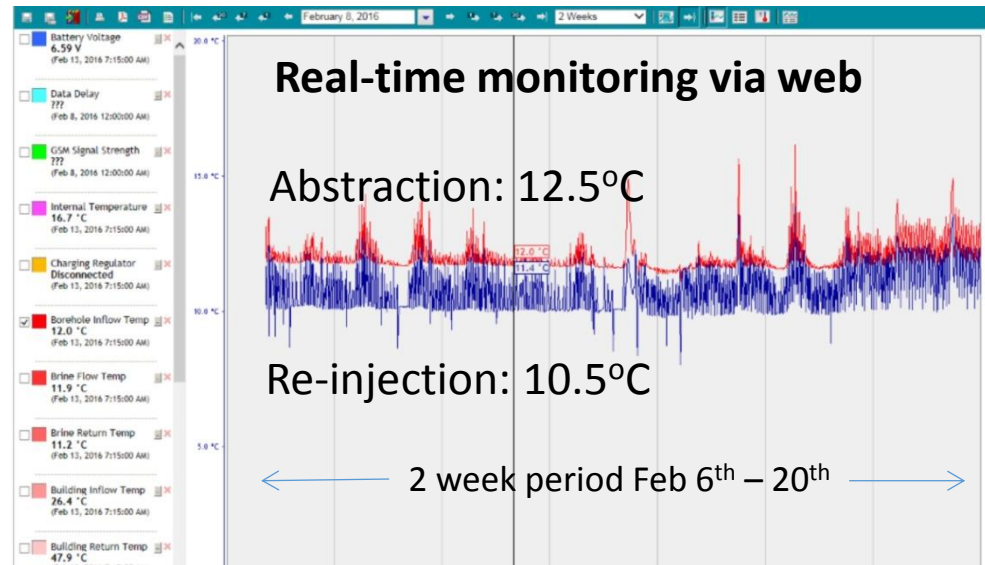
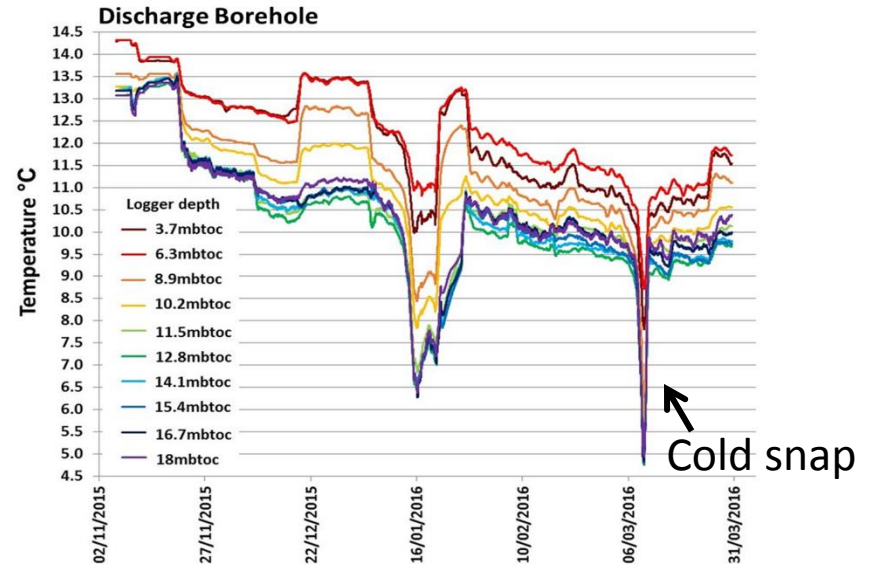
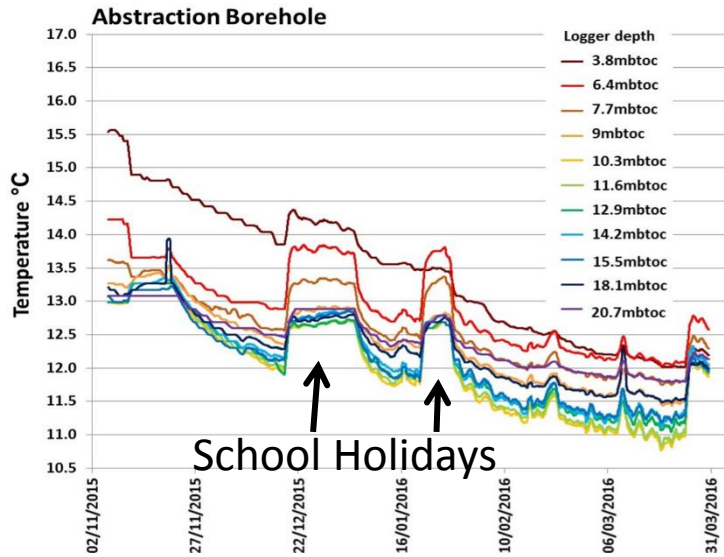
# Subsurface Monitoring Network



# GSHP Test Site: Monitoring



# Groundwater Monitoring System: Results





## Iron build-up



Abstraction Borehole (BH1).  
No iron build-up after 6 months.



Injection (return) borehole (BH2).  
Iron precipitation on the logger device.

# Ground Conditions Investigations

## Drivers for geological research:

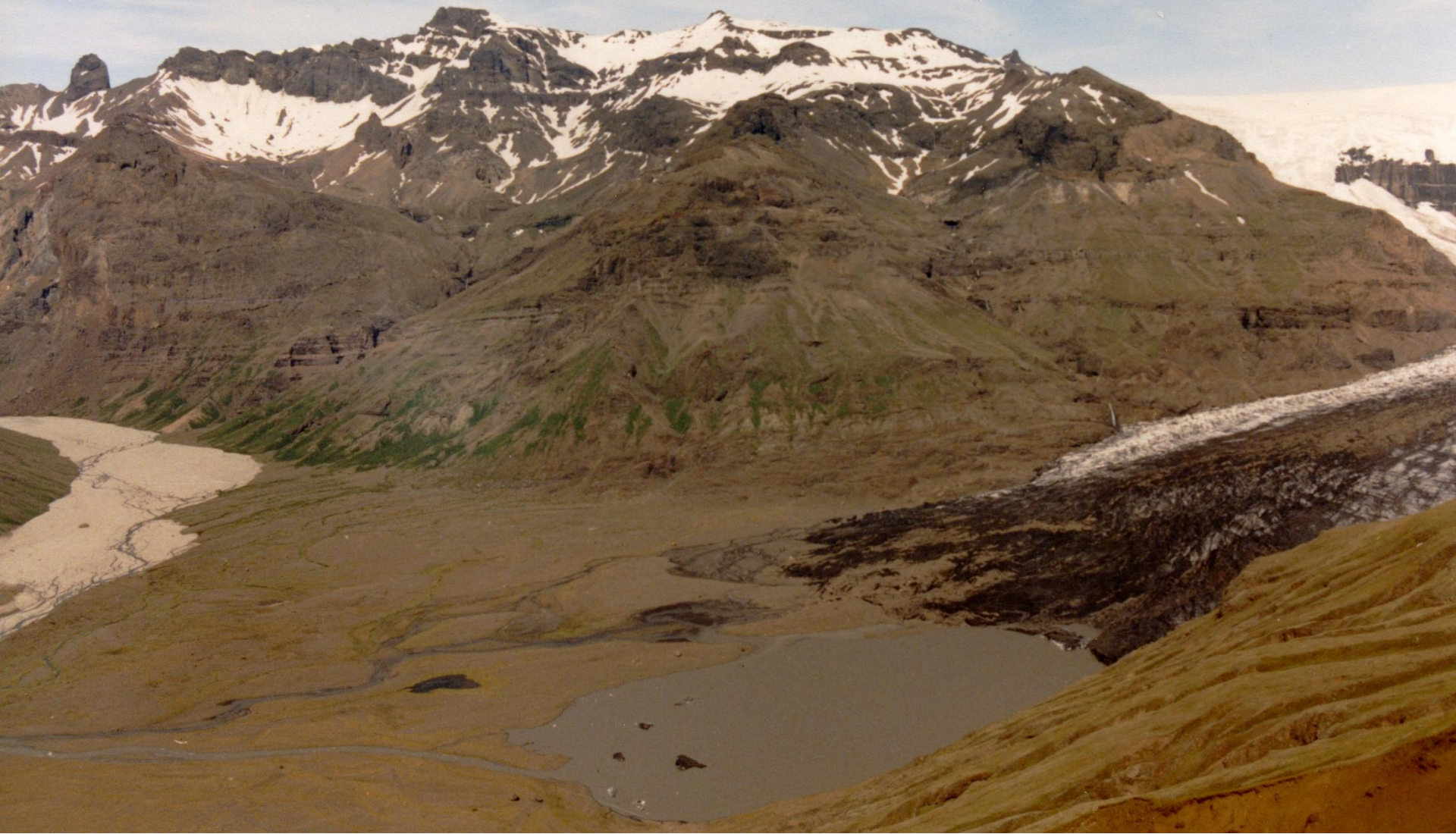
- All development & construction projects face ground 'risk' and a good geological understanding is proven to help reduce costs
- Aim of geological investigations was to provide city-scale baseline information for conceptual ground model development and GSHP feasibility planning

## Research Questions: Main issues anticipated were:

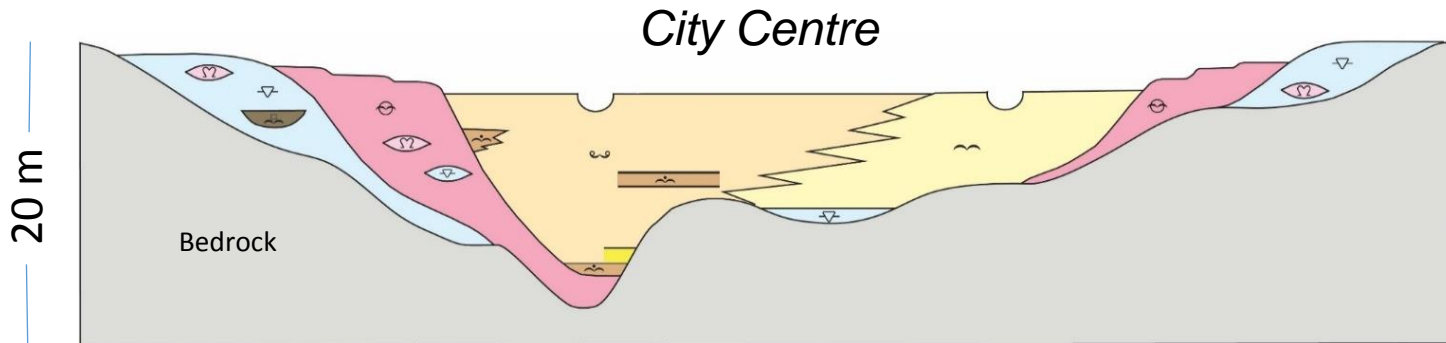
- Available groundwater volumes, variable flow direction and quality
- Variable drillability and geotechnical conditions
- Potential to encounter contaminated land, UXO
- Connection to rivers, bay, sewers ground's reaction to pumping

**Approach:** Develop a 3D geological model and simulate heat flow scenarios

Modern glacial environment, Skaftafell, in Iceland, is similar to Cardiff 15,000 BP



# Geo-system Modelling – Cross-sections & 3D Modelling

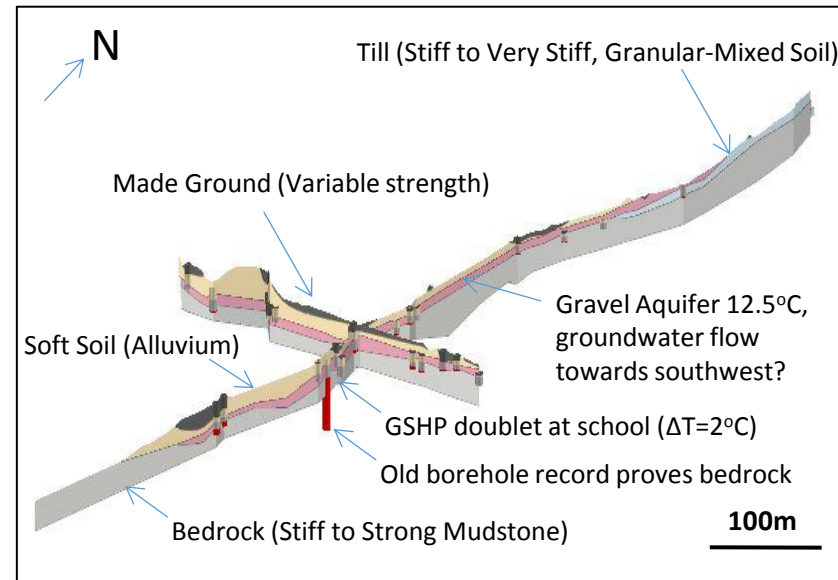


Indicative scale: Width approximately 2km Height approximately <15m

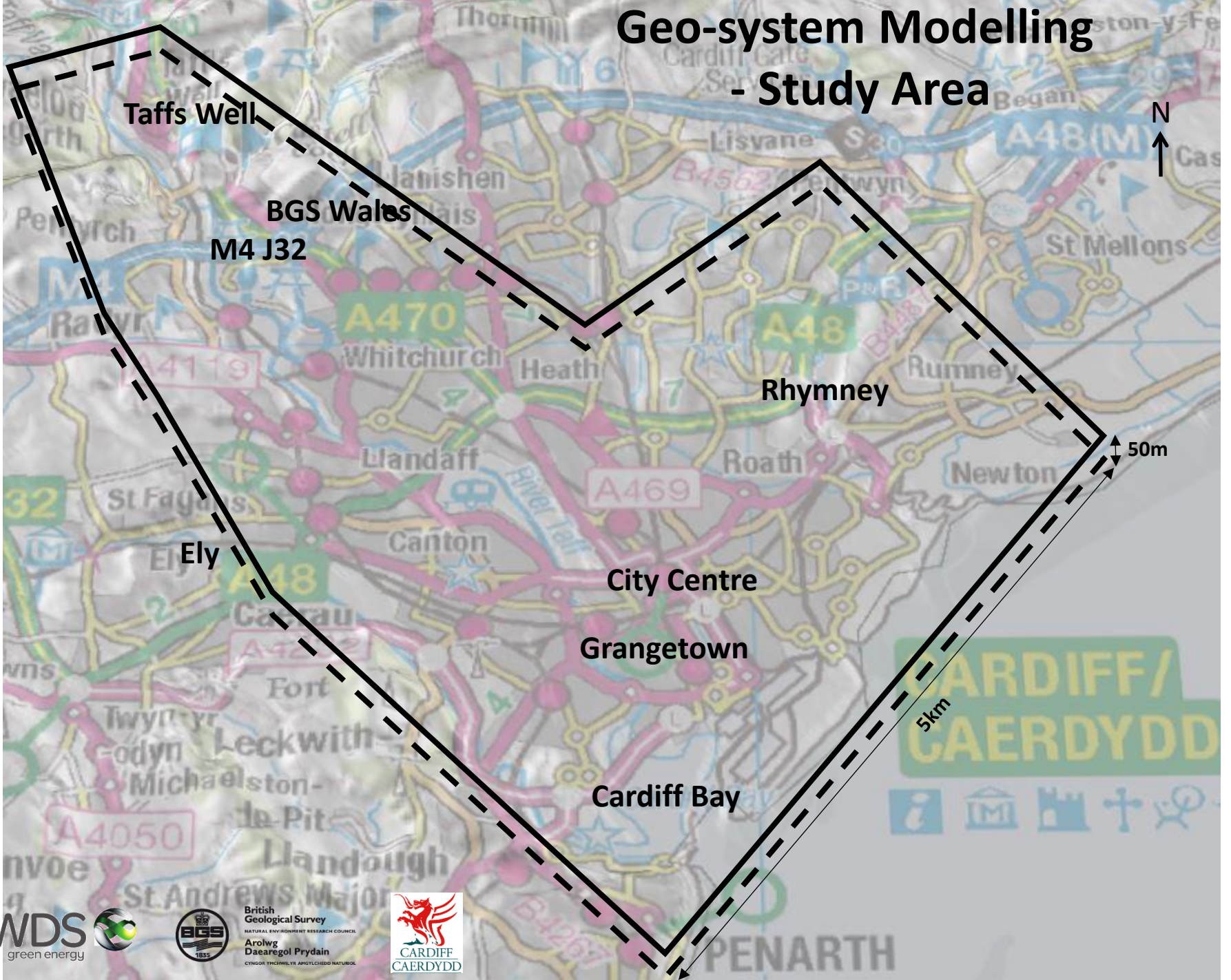
(Conceptual Cross-section. Kendall, 2015)

Aquifer

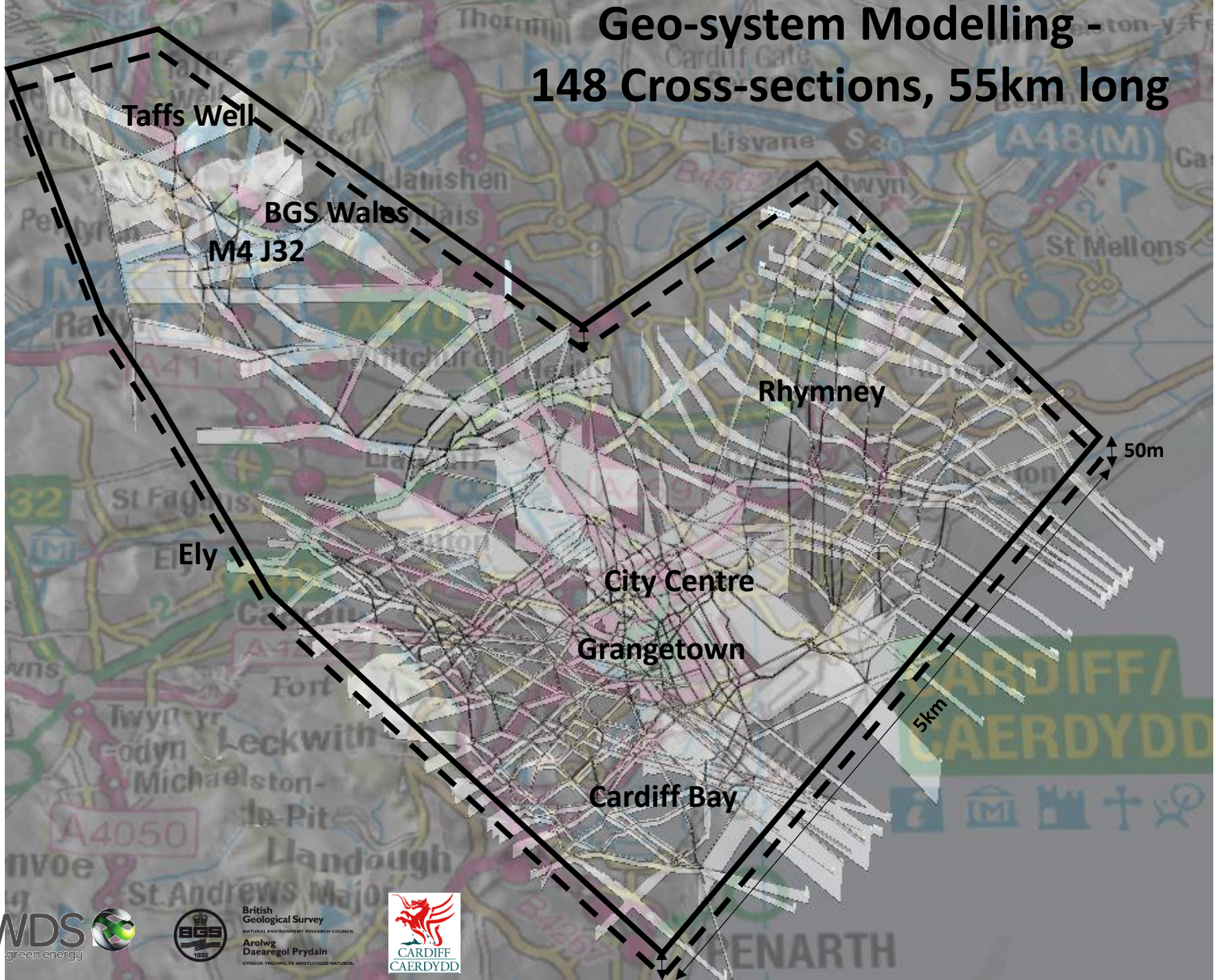
- TILL (TILL).** In the Cardiff district, the dominant type of glacial drift is gravelly till with lenses of sand and gravel. The Tills have a variable composition ranging from stiff, stony, silty clay (CSVLB) to clayey gravel (CLGV). Gravel grade material is usually pebble to cobble sized. The matrix consists of variable mixtures of sand silt and clay. Lenses of sand and gravel (SAGR) are sands and sandy pebble-cobble gravels which are commonly cross bedded.
- Hummocky (Moundy) Glacial Deposits (HMGD).** Glacial sand and gravel deposits of the Cardiff memoir are here referred to as Hummocky Glacial Deposits. These comprise chaotic sandy pebble-cobble gravel (VSL) with lenses of locally pebbly sand (SAGR), laminated clay (GLD-C) and gravelly till (CLGV).
- Glaciofluvial Sheet Deposits (GFSD).** Clayey sandy pebble-cobble gravels (CSVLB) with thin beds of gravel which are matrix free (SAGR). GFSD is often overlain by very fine clayey sand/silt (CS). May be cryoturbated in upper parts.
- Glaciolacustrine (GLD).** Laminated clays (C) occur in lenses throughout the TILL and HMGD
- Tidal Flat Deposits (TFD).** In the Cardiff district, these deposits are referred to as Estuarine Alluvium. The deposit mainly comprises clay with very subordinate silts, sands and gravels (CZSV). A peat is commonly present at the base (PEAT-PEAT) and scattered thin peats (PEAT-CPS). Interbeds of sand and gravel (SAGR) are noted in borehole logs.
- Alluvium (ALV).** Variable deposits, commonly clay, sand and gravel (CZSV) and sand and gravel which could be the same deposit with the fines washed away.
- Peat (PEAT)** A diachronous basal peat is commonly present at the base of the Tidal Flat deposits as well as occurring as scattered thin layers. The basal peat is well developed beneath the former East Moors Steelworks site but rarely present beneath the estuaries. Two other higher peats are also recorded from boreholes. Peat is also recorded as accumulating in kettle-holes on the supraglacial till complex.
- Basal Gravels** occur at or near the base of the Tidal Flat Deposits and are impossible to distinguish from older fluvioglacial gravels unless separated by a basal peat.
- Bedrock, undifferentiated.**



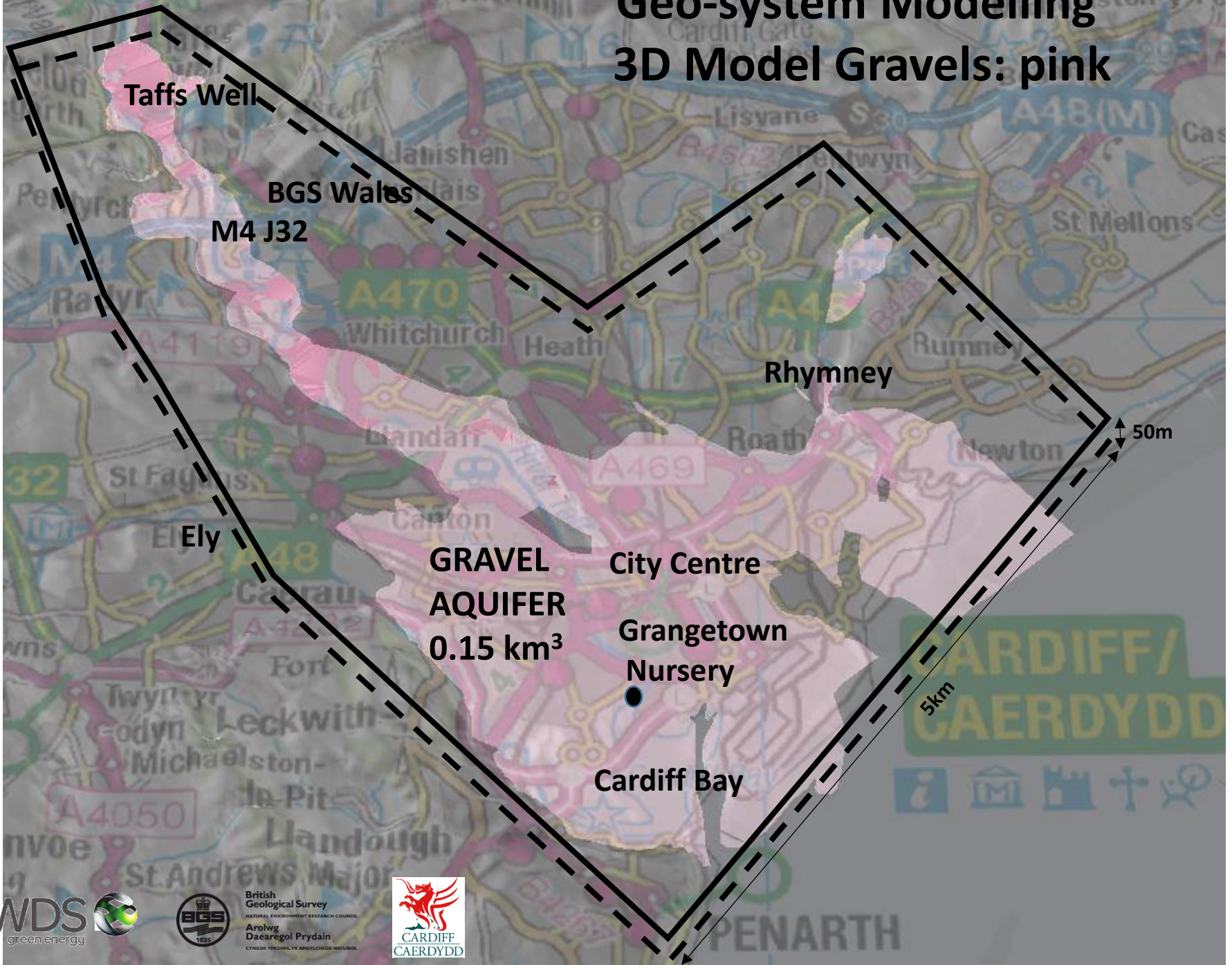
# Geo-system Modelling - Study Area



# Geo-system Modelling - 148 Cross-sections, 55km long



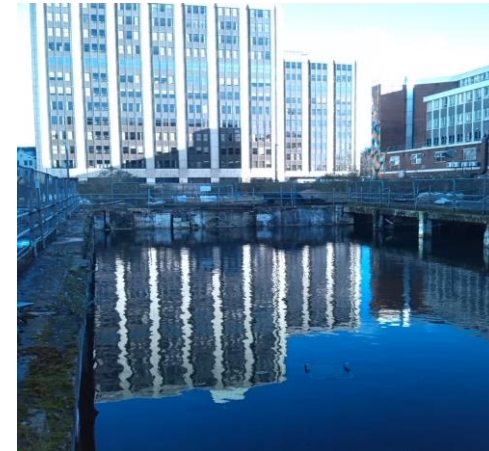
# Geo-system Modelling 3D Model Gravels: pink



# Shallow Groundwater Volume Estimate

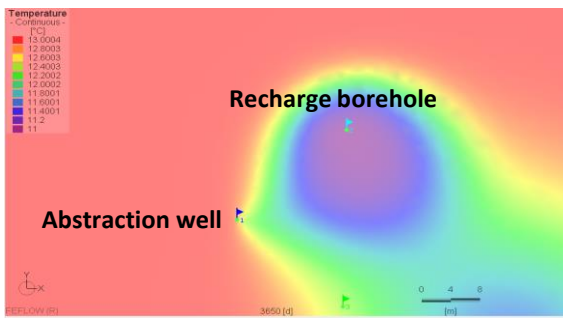
## Fact:

- Our model shows 25% (38km<sup>2</sup>) of Cardiff sits on a shallow aquifer\* 5m to 10 m thick of sand and gravel
  - Volume of the main glacial gravel is approx 0.18km<sup>3</sup>
  - When we assume it is water-saturated with porosity of 20%, volume of water is 28 Billion Litres at ~12°C \*\*
- ...Initial estimates / don't include deeper groundwater



\*Flooded Basement in Cardiff showing shallow water table 3m-4m below your feet

- ## Questions:
- (1) How much heat can we abstract? \*\*\*
- (2) Does heat recharge 'naturally' if we stop pumping?



\*\*\*Simulated groundwater temperature drop after 10 years of operation is ~1°C



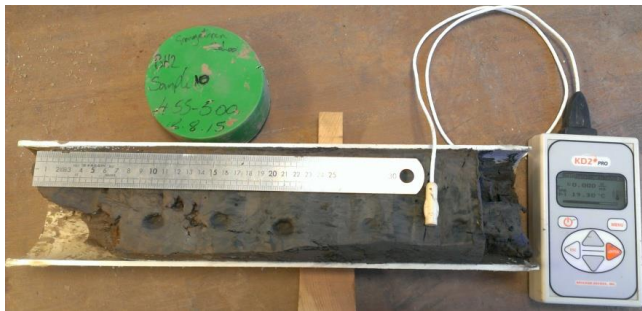
\*\* 28 Bn Litres is enough water to fill 11,000 Olympic swimming pools!



# Soil Properties

- Thermal properties of soil and bedrock affect heat flow & transfer below ground
- 186 measurements made on soil and rock cores
- 3 types of probe used to determine *Thermal Conductivity* and *Diffusivity*
- TR-1 needle probe most accurate for soils TC
- SH-1 best for *Thermal Diffusivity*

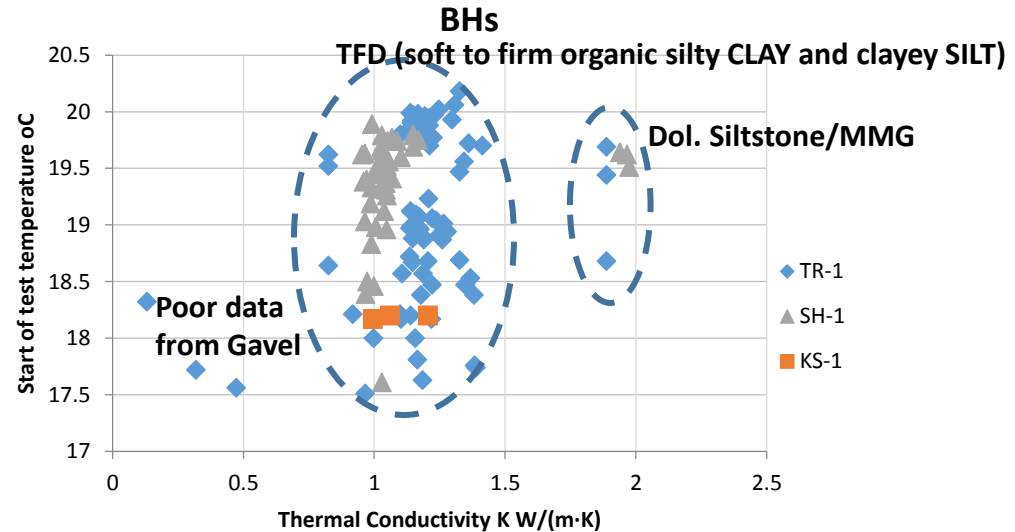
Deposit	Tidal Flat Deposit (Clay & Silt)	Mercia Mudstone Group (Siltstone)
<b>Thermal Conductivity*</b> K W/(m.K)	1.221 (TD -1) 1.027 (SH -1)	1.2 – 1.9 (Weathered – Fresh)
<b>Thermal Diffusivity</b> m <sup>2</sup> /d	0.024 (SH-1)	0.035 – 0.065 (Weathered – Fresh)



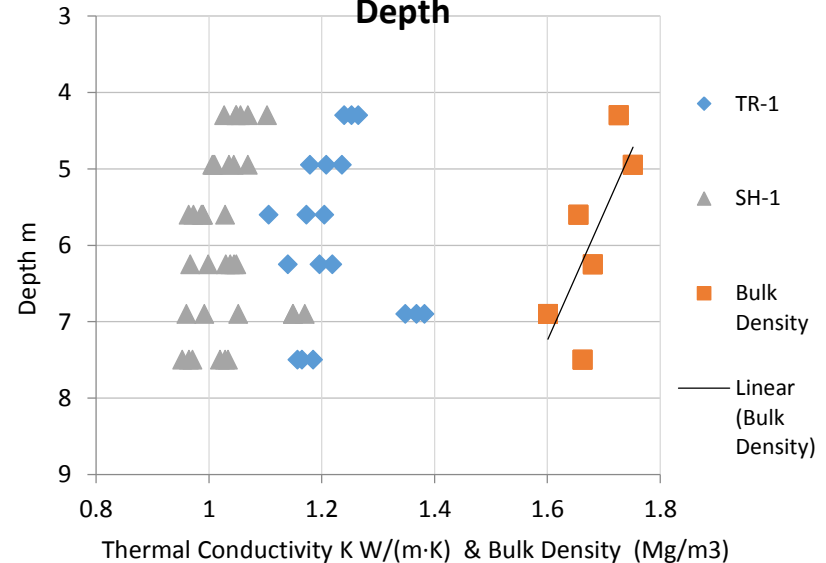
Split U100 core sample of Tidal Flat Deposits with SH-1 probe was inserted both parallel and parallel to bedding plane to measure fabric anisotropy

\* 'Geometric mean' value reported as this provides best estimate of 'bulk' Thermal Conductivity (GSHPA Standards 1.0, 2014)

## All Lab Thermal Conductivity: Grangetown



## Soil Thermal Conductivity (& Density vs Depth



# Ground Heat Network Strategy at a City Scale Dissemination



WalesOnline

Science from the core of the British Geological Survey **GEOBLOGY**

Home About Us Contribute

TUESDAY, 20 OCTOBER 2015

### How to heat a city...by Ashley Patton & David Boon

Ashley Patton and David Boon from BGS Wales explain how an exciting new project in Wales is helping to tackle fuel poverty through urban geology.

Ashley Patton and David Boon from BGS Wales explain how an exciting new project in Wales is helping to tackle fuel poverty through urban geology.

For the last year BGS scientists have been monitoring shallow groundwater temperatures across the city of Cardiff and surprisingly they found that the ground beneath the city is significantly warmer than expected. The heat lost from buildings and sewers in cities is naturally stored in the ground, as well as released to the atmosphere, in a process referred to as the Urban Heat Island effect. Our work has shown that, in Cardiff at least, this anthropogenic effect has increased the groundwater temperature from 11 to 14°C Celsius in many places. So why not use this abundant source of free, low carbon heat to warm poverty stricken homes in the city?

To learn more about our project read on...

Cardiff, a city of some 350,000 people, was once the largest exporter of coal in the world, however the majority of its docks are now silted and there has been significant urban development over the last 20 years. Cardiff is underlain by geologically young superficial deposits such as estuarine and river alluvium deposited by rivers and marine waters, and sands and gravels deposited from glacial melt waters at the end of the last ice age. This shallow sand and gravel deposits hold

Follow by email: [input field] [Submit]

SEARCH GEOBLOGY [input field] [Search]

PAST POINTS

- 2015 (7)
- November (7)
- October (9)

Soil (Geochemistry for agriculture and health, by Quality Accreditation in Inorganic Geochemistry)  
The International Ocean Discovery Program (IODP) Site  
How to heat a city by Ashley Patton & David Boon

British Geological Survey  
WDS  
Sustainable Exploitation of Elevated Groundwater Temperatures in a Shallow Urban Aquifer for Ground Source Heating

Patton, A.M.<sup>1</sup>, Farr, G.J.<sup>2</sup>, Boon, D.P.<sup>1</sup>, James, D.R.<sup>3</sup>, Williams, B.<sup>4</sup>, Tucker, D.<sup>5</sup>, Hascombe, G.<sup>6</sup> & Newell, A.J.<sup>6</sup>

<sup>1</sup>British Geological Survey, Natural Environment Research Council, Keyworth, Nottingham, UK; <sup>2</sup>Cardiff Business Academy, Queen Alexandra House, Corgan Road, Cardiff, UK; <sup>3</sup>Cardiff Business Academy, Queen Alexandra House, Corgan Road, Cardiff, UK; <sup>4</sup>Cardiff Business Academy, Queen Alexandra House, Corgan Road, Cardiff, UK; <sup>5</sup>Cardiff Business Academy, Queen Alexandra House, Corgan Road, Cardiff, UK; <sup>6</sup>Cardiff Business Academy, Queen Alexandra House, Corgan Road, Cardiff, UK

**Introduction**

UK Government has a target of reducing greenhouse gas emissions by 80% by 2050 (Climate Change Act, 2009). Ground source heating systems could contribute to the UK's green energy but a lack of sites has resulted in slow uptake. We aimed to produce the first UK city scale heat map to support the development of ground source heating. We also intended to describe groundwater temperature variation with depth and across the available thermal energy (ground to 200m).

The coastal city of Cardiff, Wales, UK, has a marine estuarine aquifer in granite over the River Mersey. Some of the grounds are locally confined by clay. In 1989 Cardiff Bay was impounded forming a freshwater lake (Cardiff Bay, hereafter 'the Cardiff Bay Reservoir'). In 1993, heat measurement for groundwater monitoring & city wide sensitive network was installed. We used 168 of these monitors to measure groundwater temperature in a residential estate.

**Methodology**

- DTf loggers in 8 boreholes recording temperature at 20cm intervals provided time series data, 10/2 years (2012-2014).
- Initial network in Spring 2014 (coast line for groundwater).
- 168 groundwater monitoring boreholes up to 200m deep - 1 mho boreholes.
- In Situ 'Rugged Temperature, Level & Conductivity Meter (TLC)' recorded temperature every 1m.
- Weather, soil & near temperature data also obtained.
- 20 boreholes in a range of geology & soil use as profiles in Autumn 2014 (overland flow for groundwater) to characterise seasonal changes & define the zone of seasonal fluctuation?

**Analysis**

- City or very shallow boreholes & anomalous data removed leaving 127 profiles.
- Data of 17° water of water residual from average to remove atmospheric temperature effects.
- Average temperature for each borehole resulting 1°mho calculated.
- Average temperature contours in Cardiff (Fig. 4).
- 20°C isotherm (red) used to produce 2D thermal resource map (Fig. 4).
- DTf/DTf (mho) used to check for heat transfer from urban domestic temperature profiles (Fig. 5).
- Borehole logs coded with lithology to characterise seasonal variation with lithology (Fig. 7).

**Results**

- In situ monitoring of 40+ boreholes in different geological unit, capturing seasonal change (Fig. 10).
- Groundwater pumping trials to assess sustainable yields & heat recharge.
- Development of water ground source heat pump heating system.
- Chemical analysis of groundwater quality to support system design.
- Monitor & 2D isotherm profile & other information to assess impact of urban infiltration.
- Development of 2D geological & hydrogeological model.
- Identify heat sources in urban centres & the relationship between temperature & geology.

**References:** Boon, J., Wright, A. & Williams, J. (2011) The National Urban Temperature Field Survey. Quarterly Journal of Engineering Geology & Hydrogeology, 44, 371-387.

Administrative Support: Ian Brown, BGS; Natural Environment Research Council; and Cardiff Council (2012) Cardiff Council.

Contact information: Ashley Patton e-mail: ashley@bgs.ac.uk tel: +44 (0)129 2052 1962

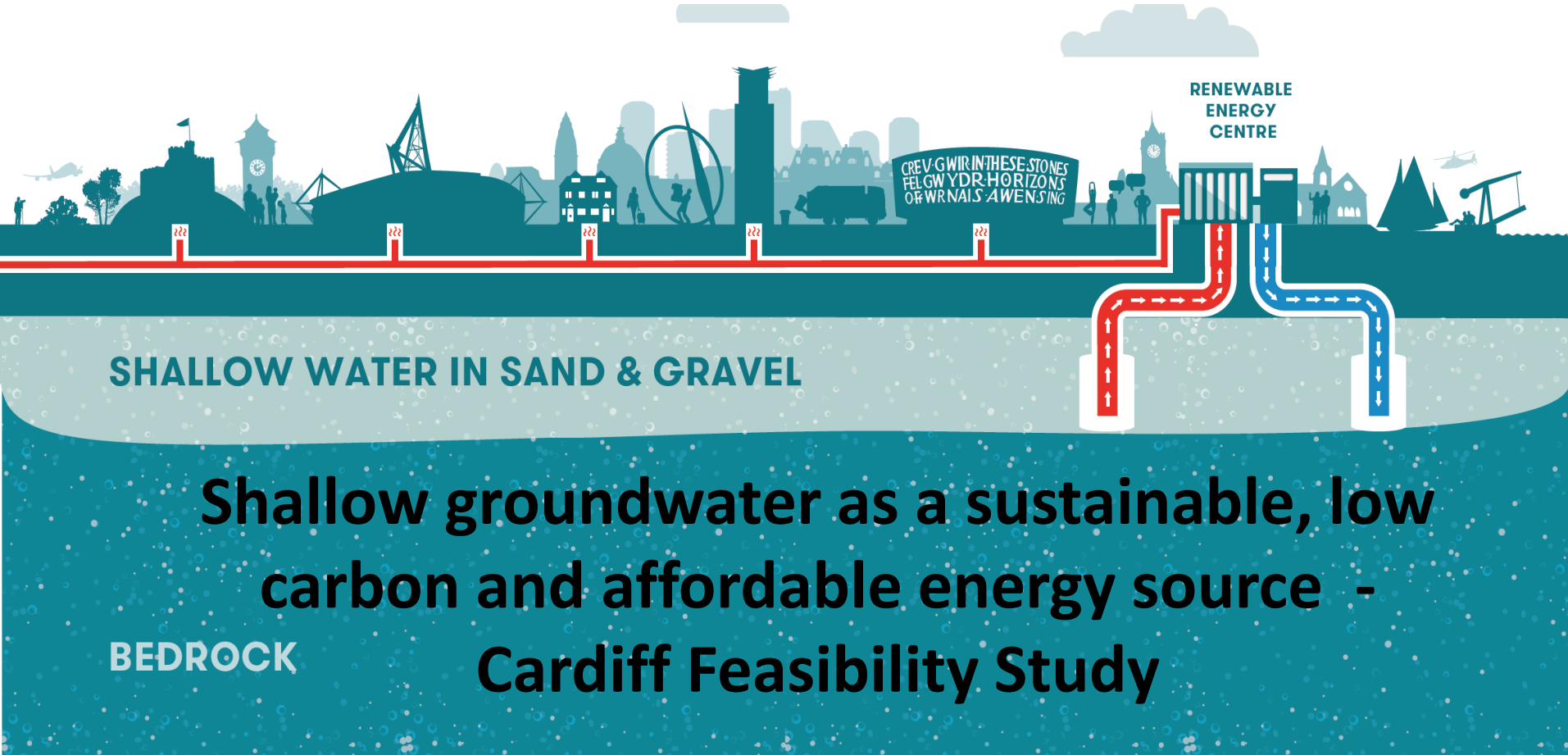
- Press Release via Cardiff Council & Capital Times
- ‘Sustainable Exploitation of Natural Resources’ Conference, London
- BBC Radio Wales [interview and tweets](#)
- Online news article [www.Walesonline.co.uk](http://www.Walesonline.co.uk)
- BGS ‘Geoblogy’ [online blog](#), Twitter, YouTube video (*showing soon!*)
- European Geophysical Union (EGU) publications 2015 & 2016
- Special Interest Group
- Geological Society of London 2016 (Cardiff & Bristol)
- CEW (June 2016)



# ENERGY CATALYST PROJECT

## Early Stage Technical Feasibility Study

### Ground Heat Network Strategy at a City Scale



# Ground Heat Network Strategy at a City Scale

## WDS Green Energy – Who are we

- A specialist renewable energy company (SME) trading for over 15 years
- Based in Cardiff serving clients in Wales and England
- Over 600 ground and air source heat pump systems installed
- MCS accredited installers
- Projects include:
  - Schools
  - Arts centres
  - Offices
  - Leisure centres
  - Retrofitted properties
  - Social houses
  - New homes
  - Village halls
  - Factories
  - Stately Homes
- Developed first mine water heating project in Wales in 2013 under the Seren Project with Cardiff University
- Subsequently short listed in 2014 for a REA award for this mine project (won By Williams F1)



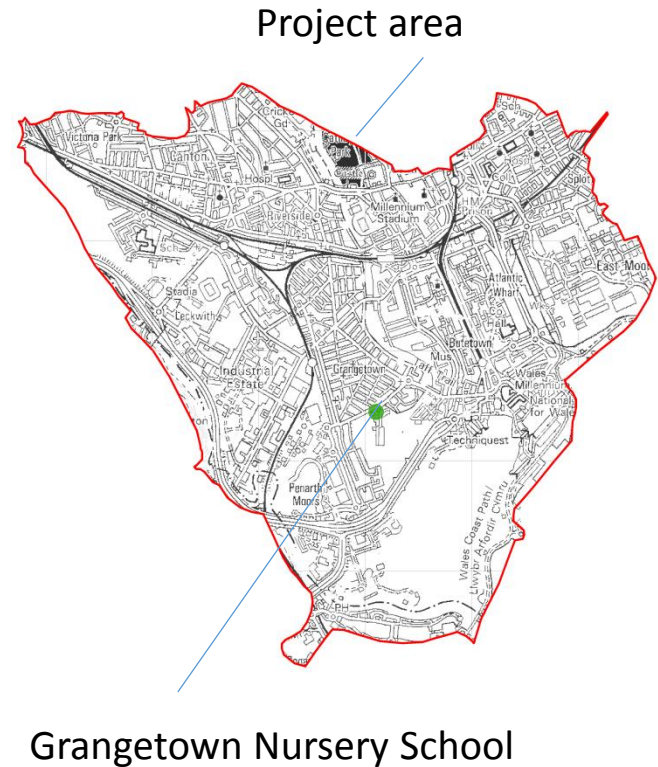
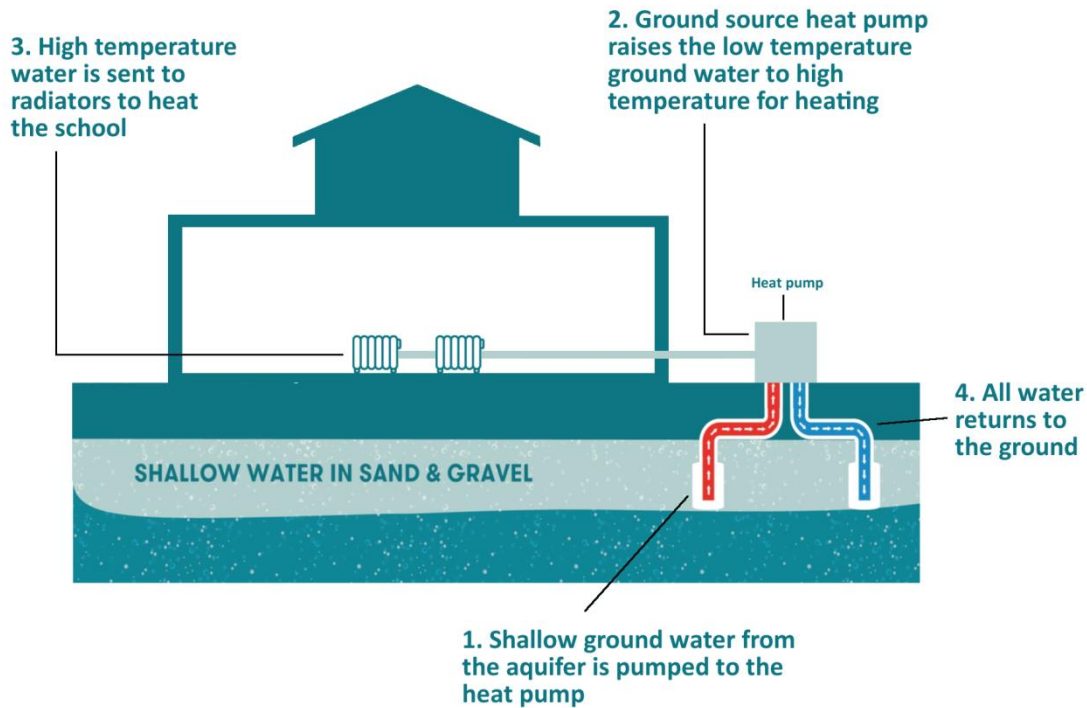
# Ground Heat Network Strategy at a City Scale

## WDS Green Energy – Role in the Project

- Project management – Innovate UK require consortia to be lead by SME's
- **Design and construct an experimental demonstration heat pump system for ground water 'testing' and to provide proof of concept**
- Help change public perception of renewable energy as an alternative to fossil fuels
- Develop an understanding of the infrastructure and restraints that may effect development of heat networks in the City
- Investigate usage of water-to-water heat pumps in the UK and European arena for best practice systems

# Ground Heat Network Strategy at a City Scale

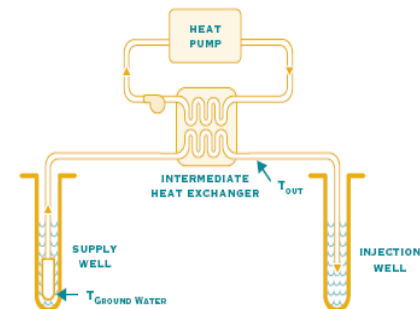
## Heat Pump project at Grangetown Nursery School



# Ground Heat Network Strategy at a City Scale

## Heat Pump System

- Site chosen – Grangetown Nursery School
  - Heating system needed upgrading
  - Sufficient space for 2 boreholes, housing and plant within school boundary
  - Boreholes shallow at 22m and water level at circa 6m
  - Heating demand allows new standalone scheme (22kW @ -3°C)
  - School head teacher is keen to promote renewables
- Works undertaken :
  - 2 boreholes - one abstraction with borehole pump ; one discharge
  - Heat exchanger
  - 2No – 11kW high temperature heat pumps
  - Buffer tank and all transfer pumps
  - Housing for all equipment
  - Heat and electricity meters and temperature loggers
  - Remote data transmission and collection



# Ground Heat Network Strategy at a City Scale

## Heat Pump System - Ground Water Works



Borehole drilling and development



Borehole pump installation



Heat exchanger, filter and flow meter



# Ground Heat Network Strategy at a City Scale

## Heat Pump System



Housing with heat pump system



Heat pump and buffer tank



Delivery pumps with loggers/metering

# Ground Heat Network Strategy at a City Scale

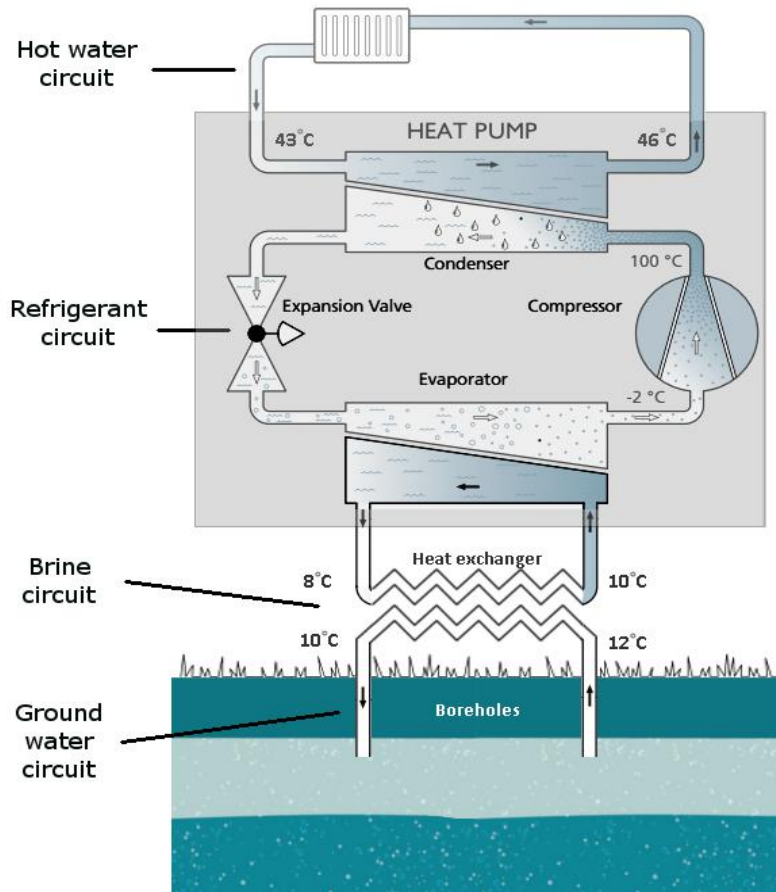
## Why Heat Pumps

- Major alternative to oil and gas fired systems
- Only uses electricity
- Utilise on-site renewable ground energy
- Produces more heat than electricity used (COP's up to 4 )
- Reduce CO<sub>2</sub> emissions
- Only renewable technology for 24/7 heating
- Government approved technology attracting Renewable Heat Incentive payments for 20 years on commercial ground source projects and 7 years for domestic air source schemes
- Suitable for new build and retrofitting properties

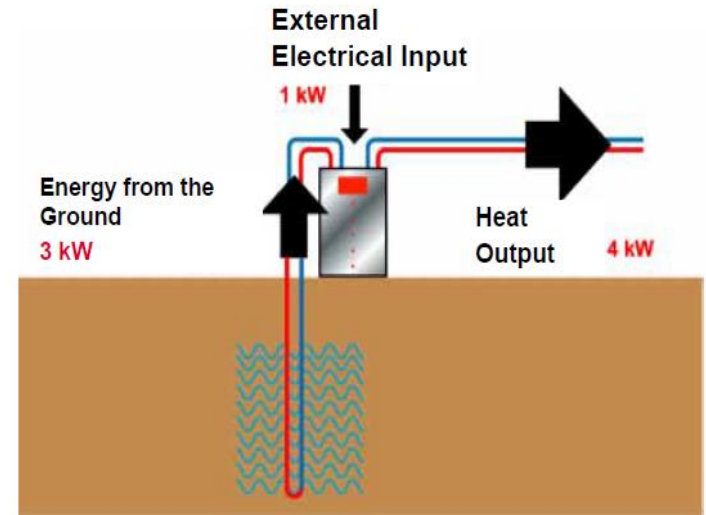


# Ground Heat Network Strategy at a City Scale

## Energy Collection



Open loop heat pump system



$$\text{CoP} = \frac{\text{Heat Output}}{\text{Electrical Input}} = \frac{4 \text{ kW}}{1 \text{ kW}} = 4$$

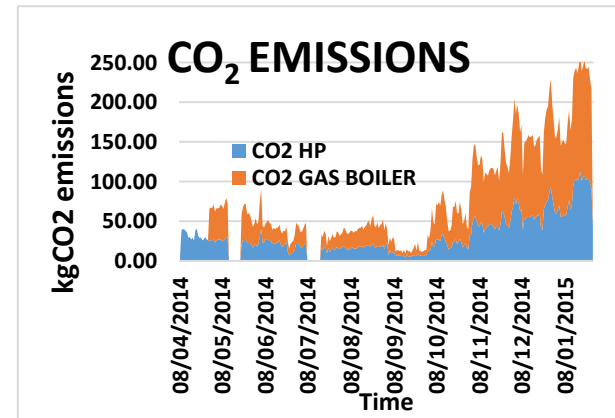
Ground water yields 75% of energy output



# Ground Heat Network Strategy at a City Scale

## Results so far – The School

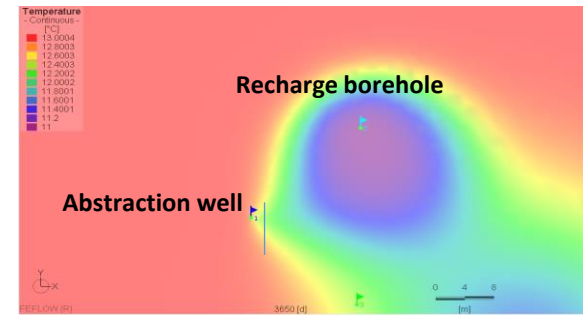
- No alterations made to the radiators in the school
- School environment comfortable for staff and children
- Radiators are safer with lower operating temperatures of circa 43°- 45°C (gas was > 75°C)
- Internal temperature monitoring to optimise flow temperatures and comfort levels
- Heating system fully instrumented with on line data
- No disruption to play activities of the school
- CO<sub>2</sub> footprint of school being reduced by circa 50%
- No gas so no potential carbon monoxide issues



# Ground Heat Network Strategy at a City Scale

## Results so far – The Engineering

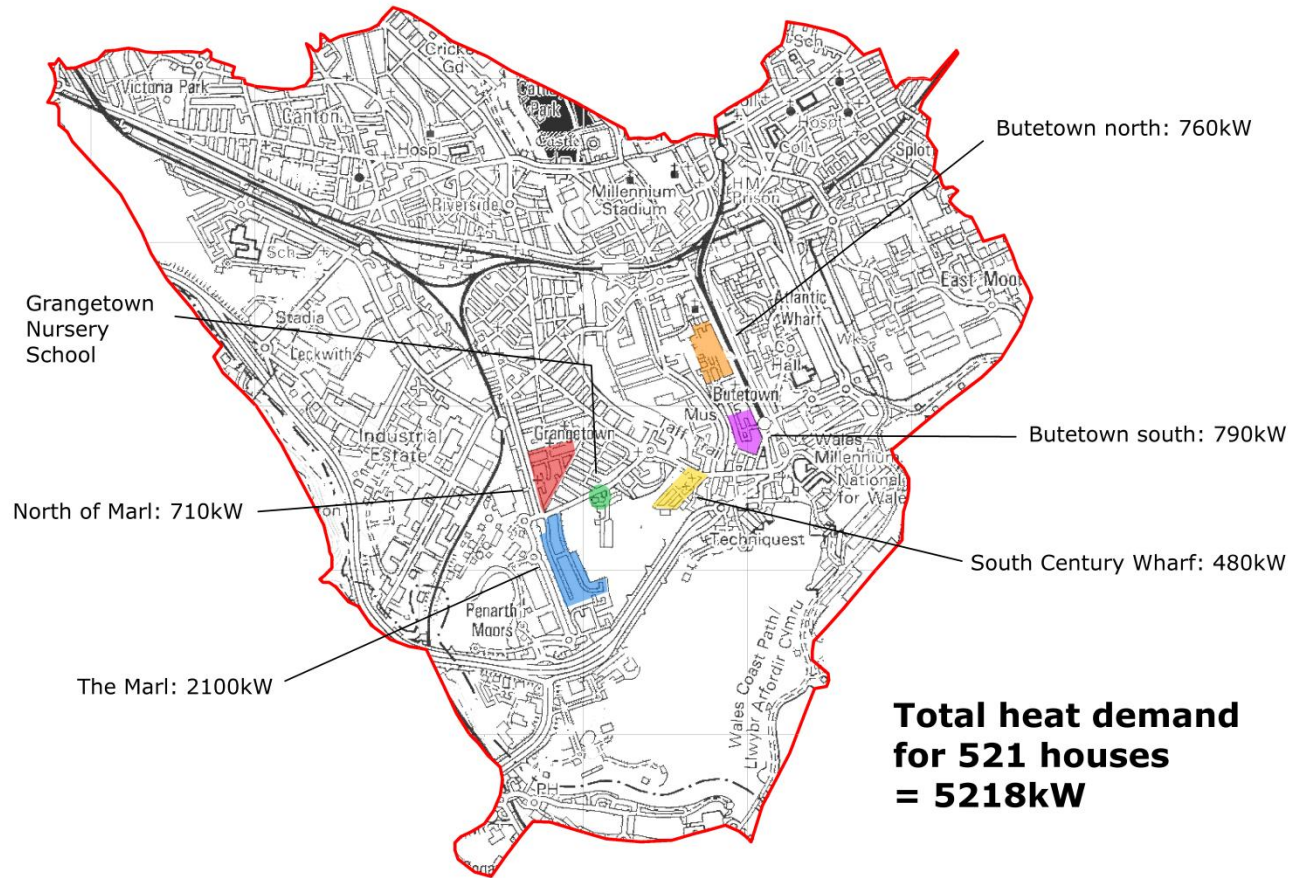
- No drawdown or increase in ground water levels during pumping regime
- Abstracted water temperatures static at circa 12°C (no cooling from discharge well)
- Flow/return delta T only 2°C for each heat pump
- 13kW heat pump output > 75% from warm ground water
- School uses **one** heat pump for most of the time
- Second heat pump only used when air temp < 3°C
- Electricity consumption minimised to 3.5kW (heat pump = 2.7kW)
- Water volume under the city circa 28 million m<sup>3</sup>
- Estimated ground water energy at delta T of 3°C > 52MW
- Proof of concept for using ground water to heat the city through networks proven



Predicted groundwater temperature after 10 years

# Ground Heat Network Strategy at a City Scale

## Heat Demand Mapping



# Ground Heat Network Strategy at a City Scale

## Future Works

- More extensive borehole drilling, test pumping and data collection
- Site specific 3D ground water modelling and validation (inter-seasonal storage)
- Investigation thermal storage potential of waste heat into ground water
- Consider open water usage – barrage and rivers
- Undertake heat demand mapping and energy planning across the city
- More detailed network distribution designs at key location
- Address utility issues from new heat networks
- Business model development – partners, funding, detailed costings
- Creation of ESCO with public and private support ?



# Ground Heat Network Strategy at a City Scale

Project mascot !



Next Steps?

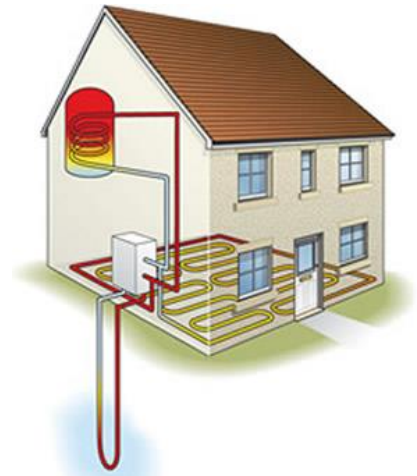
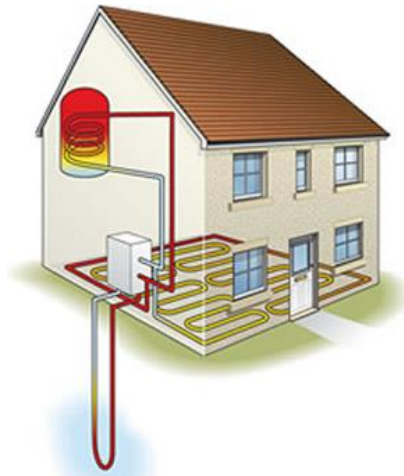
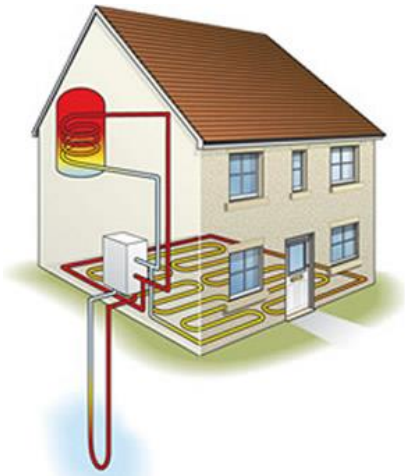
# More work needed on...

- Maximising efficiency of heat pumps?
- Value of integrating other renewables?
- Understanding customer perspective?
- Regulation and governance?
  - NRW licensing
  - Regulating heat extraction / maintaining resilience
  - Network ownership

# More work needed on...

Best system format?

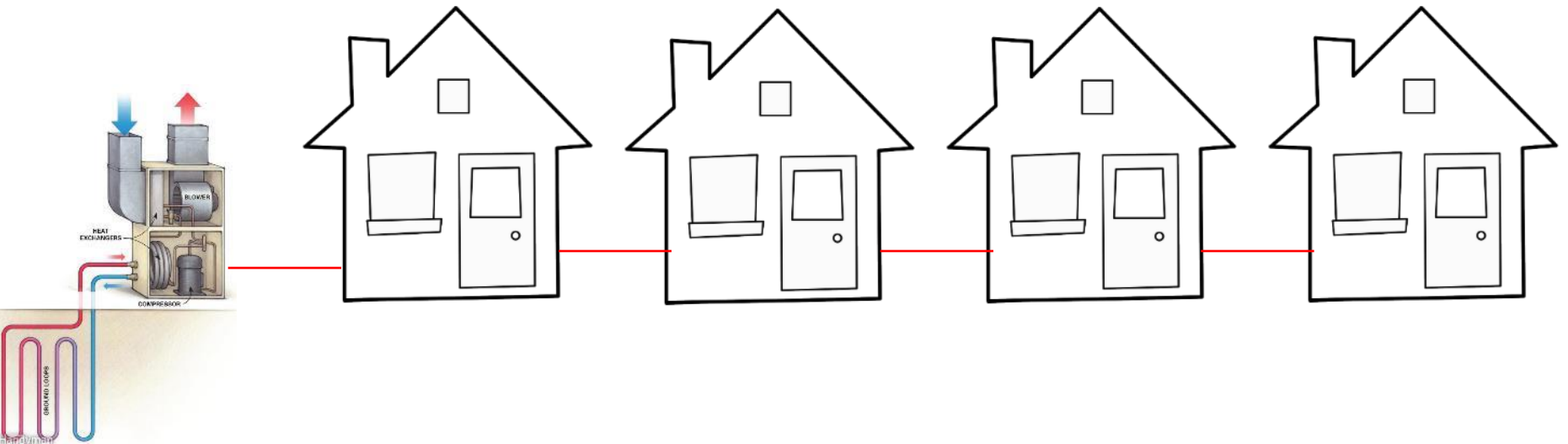
- Network of stand alone systems?



# More work needed on...

Best system format?

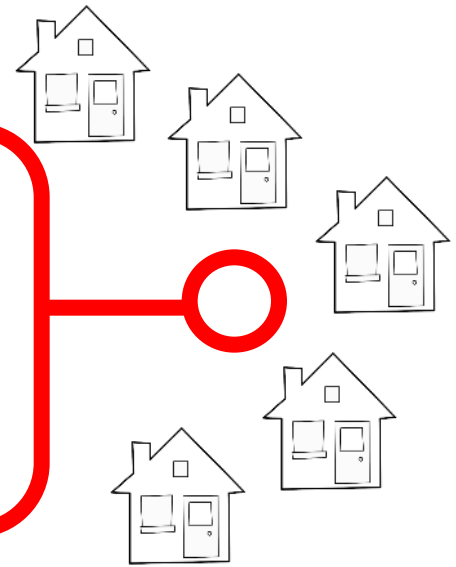
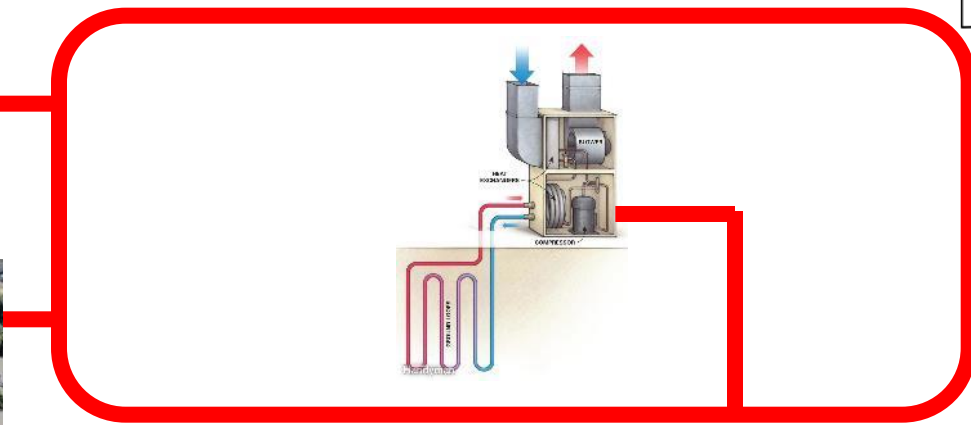
- Street/district distribution?



# More work needed on...

## Best system format?

- Part of a multi heat source network?



# Next Steps

- I-UK funding ends April 2016
- Proposing bid into 2<sup>nd</sup> 3<sup>rd</sup> stage of Energy Catalyst
- HNDU – heat mapping and technical integration work packages (Spring/Summer)
- Other support? WG/H2020/etc

# Questions & Answers





# Tour of Grangetown Nursery School

