# MCS Based Design for GSHPs – "Horses for Courses"

GSHPA Energy Expo – Stone – Sept 2017

Robin Curtis – GeoScience Ltd

GSHP association

# Dog ‘n Pony Show

Robin – on “MCS”

why / how / what / when / where

Chris – on “not-the-MCS” approach

why / how /when /where

GSHP association

# Objectives

- Background setting
- Underlying reasoning & approach
- The MIS-3005 design “products”
- Focus on the ground loop sizing &
- Hydraulics

GSHP association

# New ground loop sizing tools for Domestic GSHP installations in the UK

Robin Curtis & Tom Pine - GeoScience Ltd.

Chris Wickins - UK Dept. of Energy & Climate Change

EGC – Pisa June 2013

GSHP association

1st UK Closed Loop GSHP Domestic installation
1995 Devon (~8kW)

22 years - 1st routine maintenance/inspection this year.
(apart from air-filter changes)

GSHP association

# Background

GSHP association

**Getting warmer: a field trial of heat pumps**

The Energy Saving Trust

energy saving trust

The “infamous” EST study

…the intentions……..

…the unintended consequences

GSHP association

# DECC steps in…….

# Revise guidance for all domestic heating heat pumps (MIS 3005)

For all heat pumps (ie ASHPs and GSHPs):

Improve building heat loss estimation

Produce a Heat Pump Emitter Guide

Require ~ 100% heat pump sizing
(for mono-energetic systems)

GSHP association

# Specifically for GSHPs -

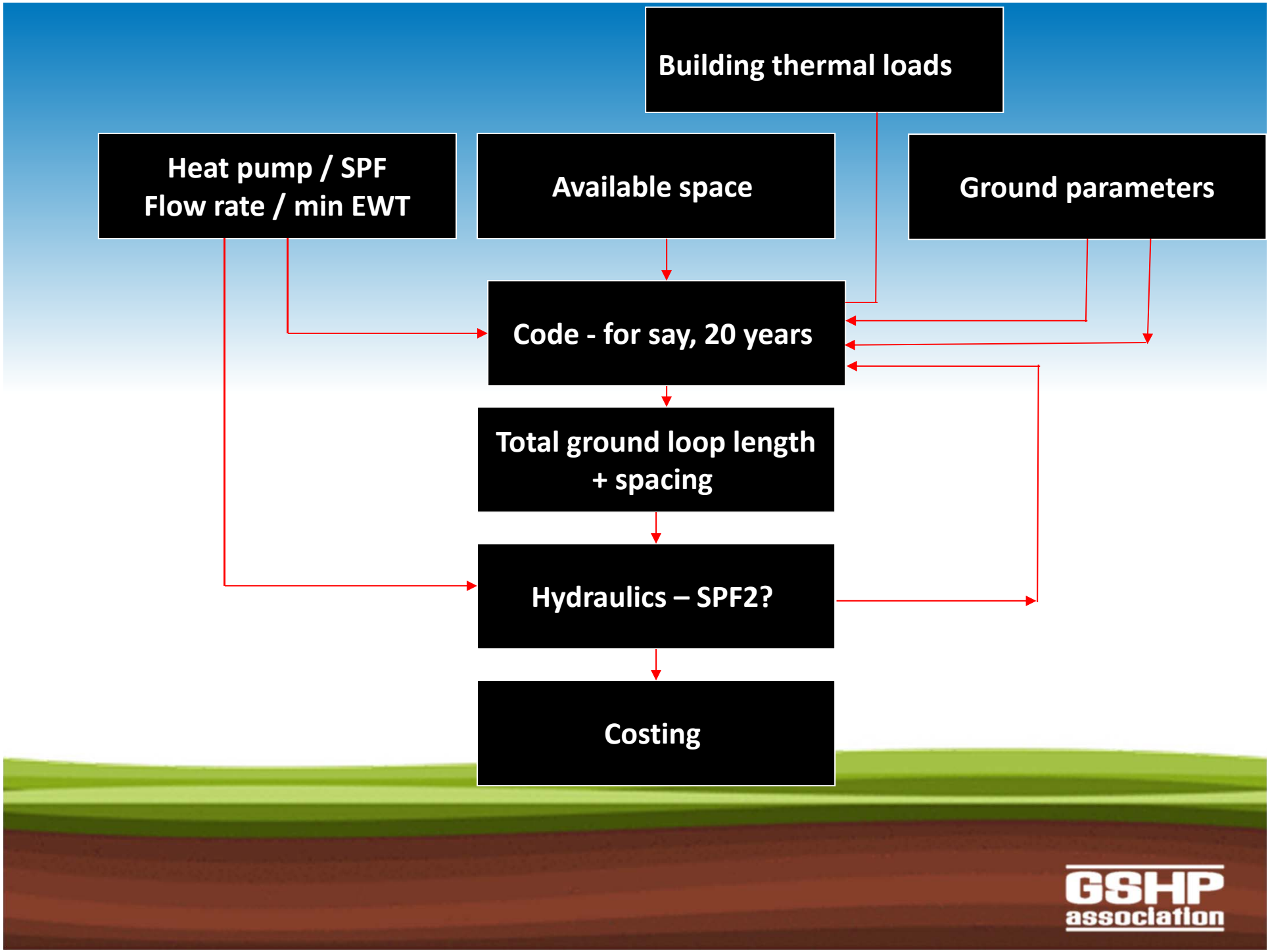
New guidance for ground loop sizing

Guidance for hydraulic  design

GSHP association

# “Crazy” paving ?

GSHP association


Building thermal loads
Heat pump / SPF
Flow rate / min EWT
Available space
Ground parameters
Code - for say, 20 years
Total ground loop length
+ spacing
Hydraulics – SPF2?
Costing
GSHP
association

# Heat loss / energy ?

GSHP association

# Energy assessment for closed loop GSHPs– “THE” fundamental difference

(compared to all fossil fuel boilers, direct electric, and ASHPs )

GSHP association

NOT your worry

Your worry

Your worry

Gas

LPG

Oil

Air

Heat generator

# Conventional – non GSHP heating

GSHP association

YOUR worry

Your worry

Your worry

Heat generator

# GSHP heating

GSHP association

# Not dealing with it here -

Other than:

1) FLEQ's

Annual kWh / heat pump size kW

Ground impact ?

2) Estimated SPF (heat emitter guide)

Ground impact

Your worry

GSHP association

# Ground loop sizing / design

GSHP association

# Underlying philosophy

- Conservative
- Simple – available to all
- Paper based – no HW/SW version issues
- Domestic heating + DHW only (<45kW)
- To obtain acceptable SPFs
- Not the best or cheapest

GSHP association

# Previous methods ?

Some use of software, eg EED, GLHEPRO, GLD, CLGS

European manufacturers' software

VDI 4640

The well known ROT method

Concerns ?  Relevance to UK conditions ?

GSHP association

# “Ground” rules

100% sizing – for mono-energetic systems

Minimum entering water temperature
(EWT) O°C
(after 20 years) – to maintain SPF

GSHP association

# Boreholes

Fixed parameters:

single 32mm U-tube, specified borehole resistance, minimum spacing defined

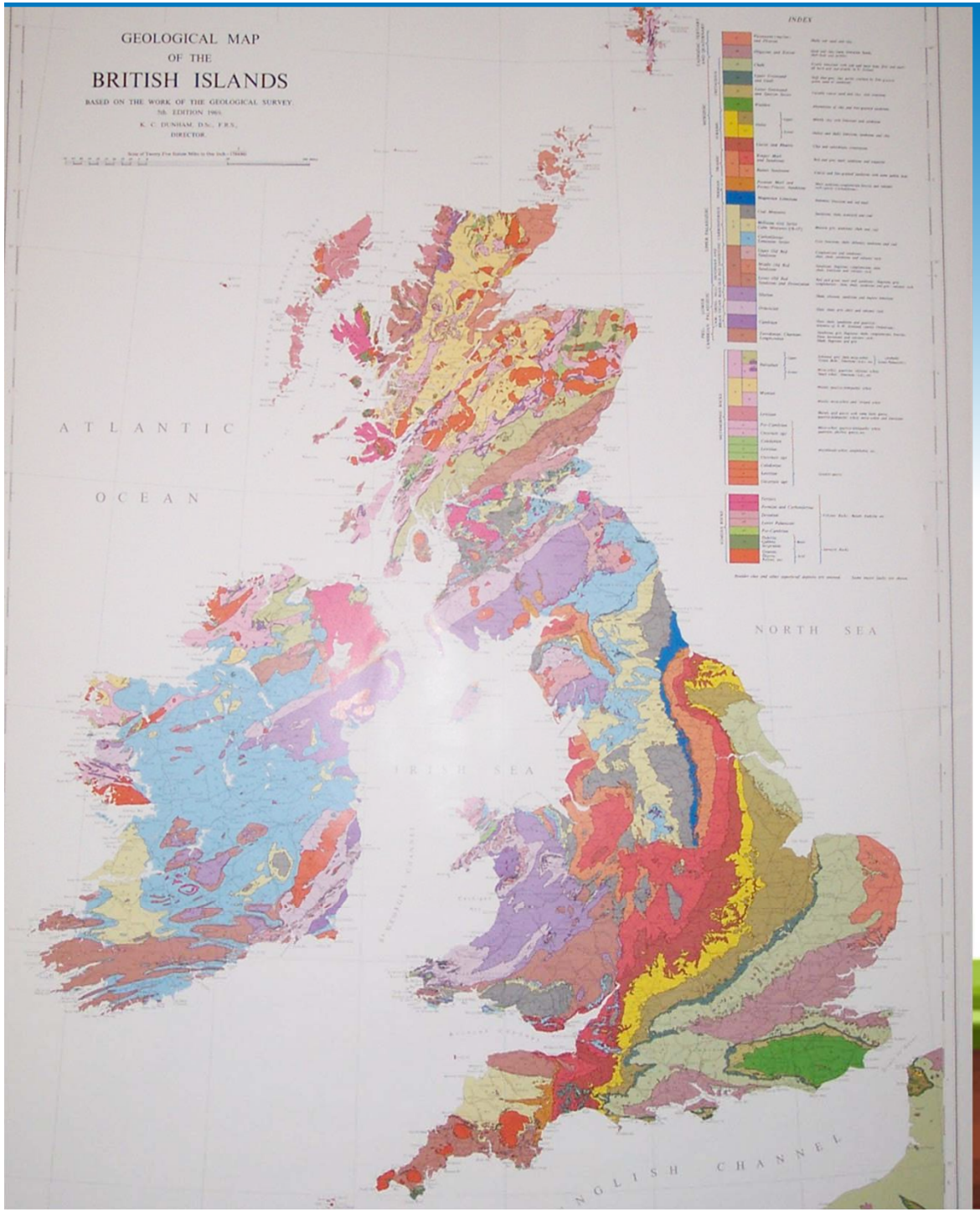
Variable parameters:

Ground equilibrium temperature

Thermal conductivity

Annual thermal loads (Run hours / FLEQ)

GSHP association




for all UK

geology
&
climate

GSHP association

# Boreholes

Over a (UK relevant) range of k, ground temperature and FLEQ

Run: EED, GLHEPRO

Make some check comparisons with VDI 4640 and GLD.

GSHP association

# Ground loop sizing….

NB – for domestic sub 45kW ONLY – heating only

Maximum power to be extracted per unit length of borehole heat exchanger (W/m) with 3600 FLEQ run hours

Conditions for use:

Heat extraction only (inc. hot water)

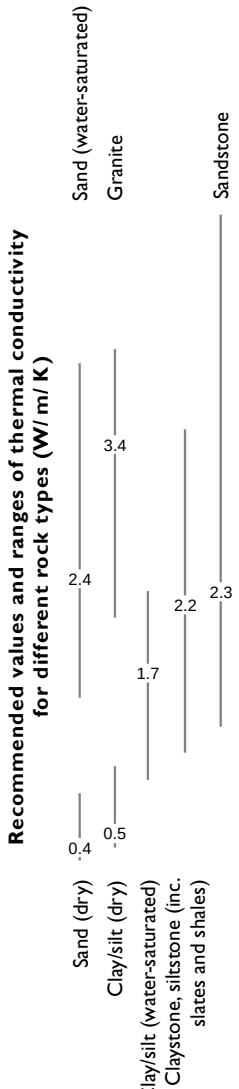
6m minimum borehole spacing. Only valid for boreholes arranged in a line; not applicable for a large number of systems in a small area

Table created assuming: 130mm borehole diameter; single U-tube; 32mm OD SDR-11, PE100 pipe with thermal conductivity = 0.420W/m/K; 52mm pipe centre-pipe centre shank spacing; 25% Mono Ethylene Gylcol thermal transfer fluid; Re > 2500 in the borehole active elements; thermally enhanced grout with thermal conductivity = 2.4W/m/K

Assumptions result in borehole thermal resistance = 0.1 m.K/W at 12°C mean ground temp. and 2.5W/m/K average ground thermal conductivity

| Average ground thermal conductivity (W/ m/ K) | Mean annual air temperature for UK regions (°C) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 6.0 | 7.0 | 8.0 | 9.0 | 10.0 | 11.0 | 12.0 | 13.0 | 14.0 | 15.0 |
| 5.0 | 29 | 32 | 37 | 41 | 45 | 49 | 53 | 57 | 61 | 66 |
| 4.0 | 25 | 28 | 32 | 35 | 39 | 43 | 46 | 49 | 53 | 57 |
| 3.0 | 20 | 23 | 26 | 29 | 32 | 34 | 37 | 40 | 43 | 46 |
| 2.0 | 14 | 16 | 18 | 21 | 22 | 24 | 26 | 28 | 30 | 32 |
| 1.0 | | | | | | | | | | |

NE Scotland, NW Scotland, E Scotland, Borders, W Scotland, Northern Ireland, North-eastern, North-western, Midlands, Wales, E Pennines, W Pennines, East Anglia, South-eastern, Southern, Severn Valley, South-western, Thames Valley



# Horizontal systems

Conventional EU style loops (Serpentine) , and Slinkies

Fixed parameters: Geometrical layouts and pipe sizes defined.

Variable parameters:

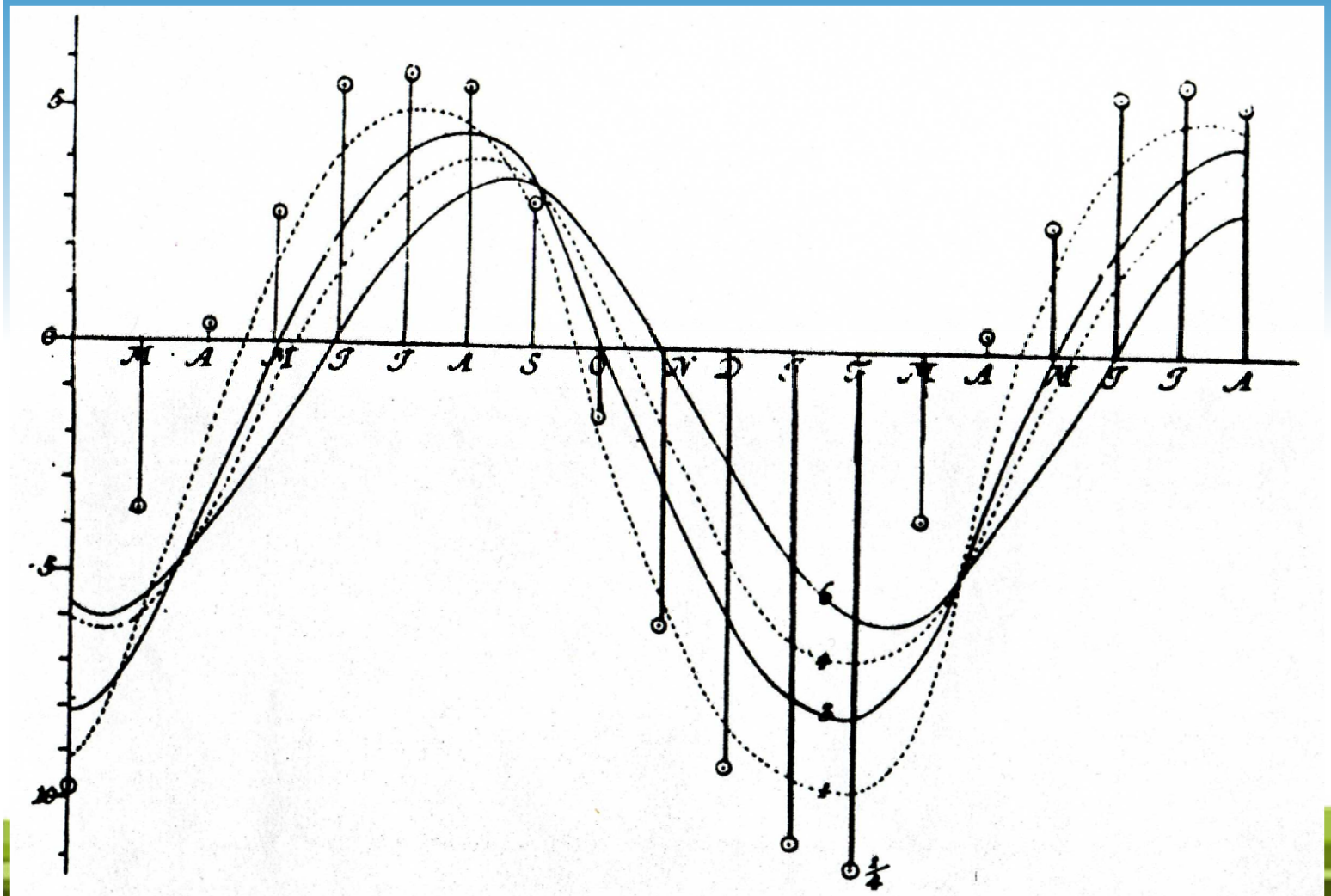
Ground equilibrium temperature

Thermal conductivity

Annual thermal loads (Run hours / FLEQ)

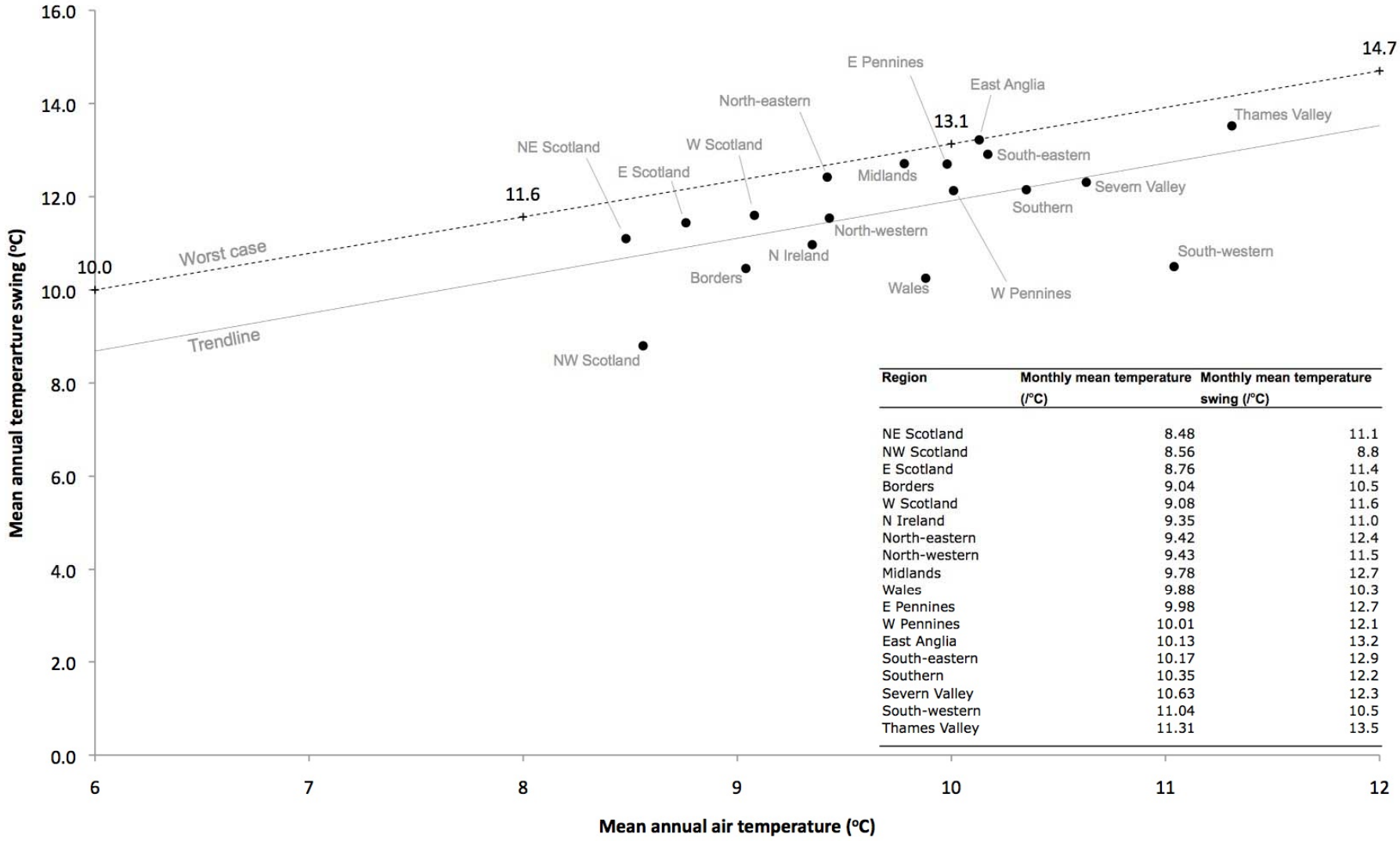
+ Temperature “swing” and depth

GSHP association



J. H. Lambert, *Pyrometrie* (Berlin, 1779).

GSHP association




| Region | Monthly mean temperature (/°C) | Monthly mean temperature swing (/°C) |
|---|---|---|
| NE Scotland | 8.48 | 11.1 |
| NW Scotland | 8.56 | 8.8 |
| E Scotland | 8.76 | 11.4 |
| Borders | 9.04 | 10.5 |
| W Scotland | 9.08 | 11.6 |
| N Ireland | 9.35 | 11.0 |
| North-eastern | 9.42 | 12.4 |
| North-western | 9.43 | 11.5 |
| Midlands | 9.78 | 12.7 |
| Wales | 9.88 | 10.3 |
| E Pennines | 9.98 | 12.7 |
| W Pennines | 10.01 | 12.1 |
| East Anglia | 10.13 | 13.2 |
| South-eastern | 10.17 | 12.9 |
| Southern | 10.35 | 12.2 |
| Severn Valley | 10.63 | 12.3 |
| South-western | 11.04 | 10.5 |
| Thames Valley | 11.31 | 13.5 |

# Horizontal systems

Over a (UK relevant) range of :

k, ground temperature and FLEQ

Run: CLGS

Make some check comparisons

with VDI 4640 and GLD.

GSHP association

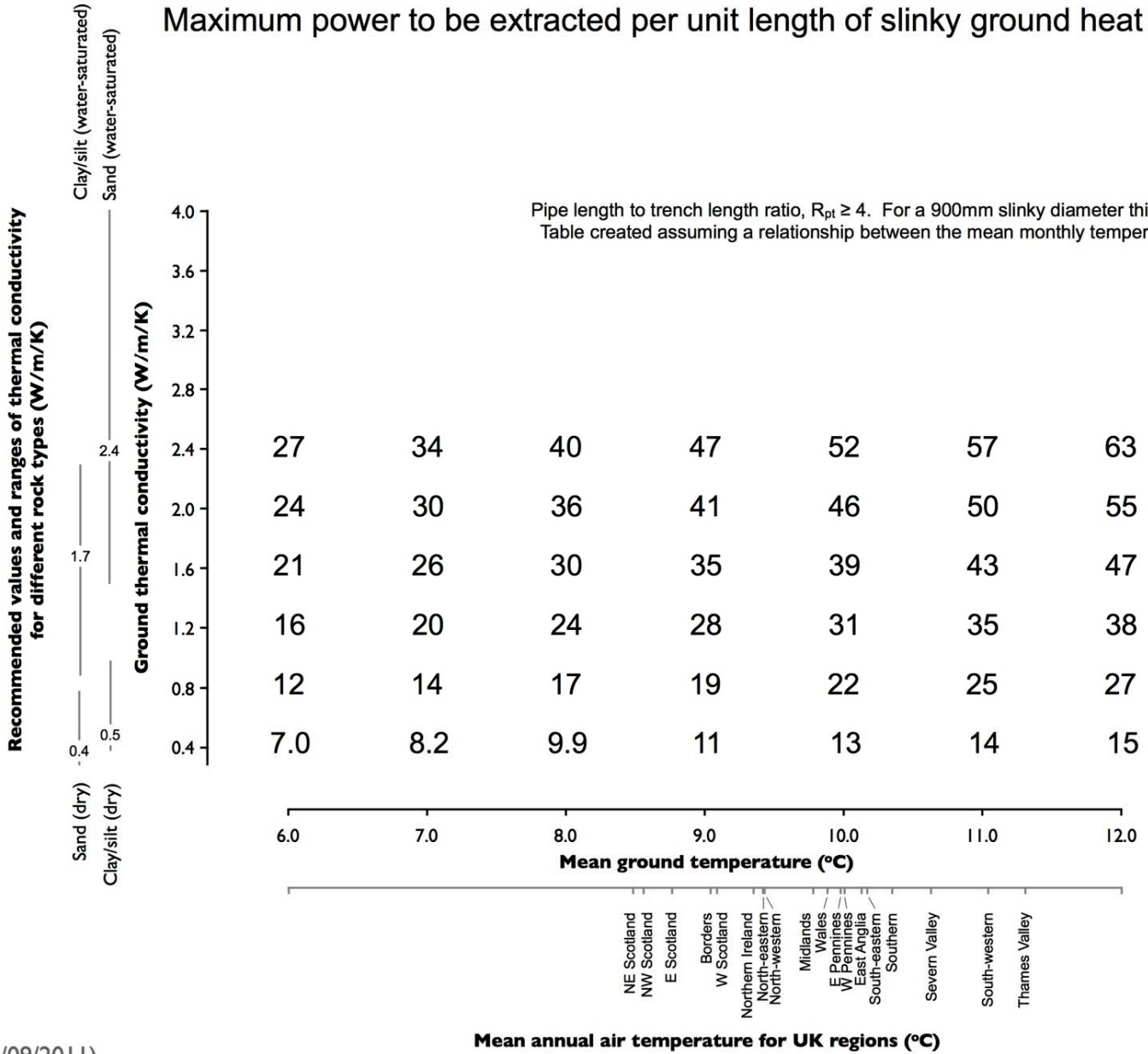
# Ground loop sizing….

NB – for domestic sub 45kW ONLY – heating only

Maximum power to be extracted per unit length of slinky ground heat exchanger trench (W/m) with 2400 FLEQ run hours

Conditions for use:

Heat extraction only (inc. hot water)
3m minimum trench spacing (d ≥ 3m)
Mean slinky depth between 0.8m and 1.2m
Table created assuming 32mm OD SDR 11 pipe
Pipe length to trench length ratio, $R_{pt} \geq 4$. For a 900mm slinky diameter this corresponds to a maximum 1250mm slinky pitch
Table created assuming a relationship between the mean monthly temperature swing and annual mean ground temperature



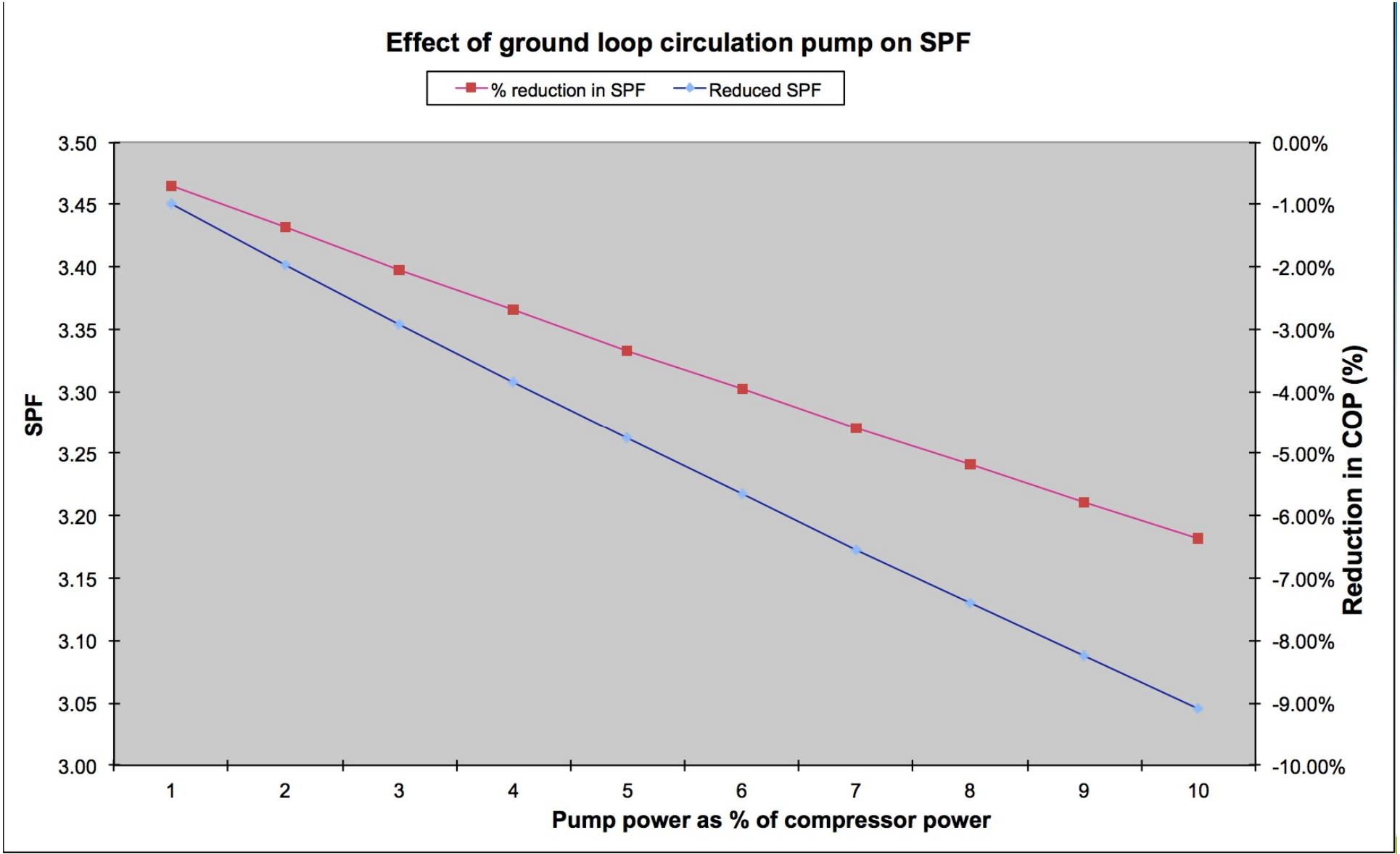
# Hydraulics design of closed loop GSHPs

GSHP association

# The challenge !!

An oversized circulation pump
consumes electricity!
Ruins performance!

GSHP association




GSHP association

# Hydraulics - Pressure drop components:

1) Active element(s)
2) Headers
3) Heat pump
4) + contingency/fittings

GSHP association

# Hydraulics - fixed parameters

- Heat pump flow rate
- Non-laminar – (transition zone)
- min % Anti-freeze

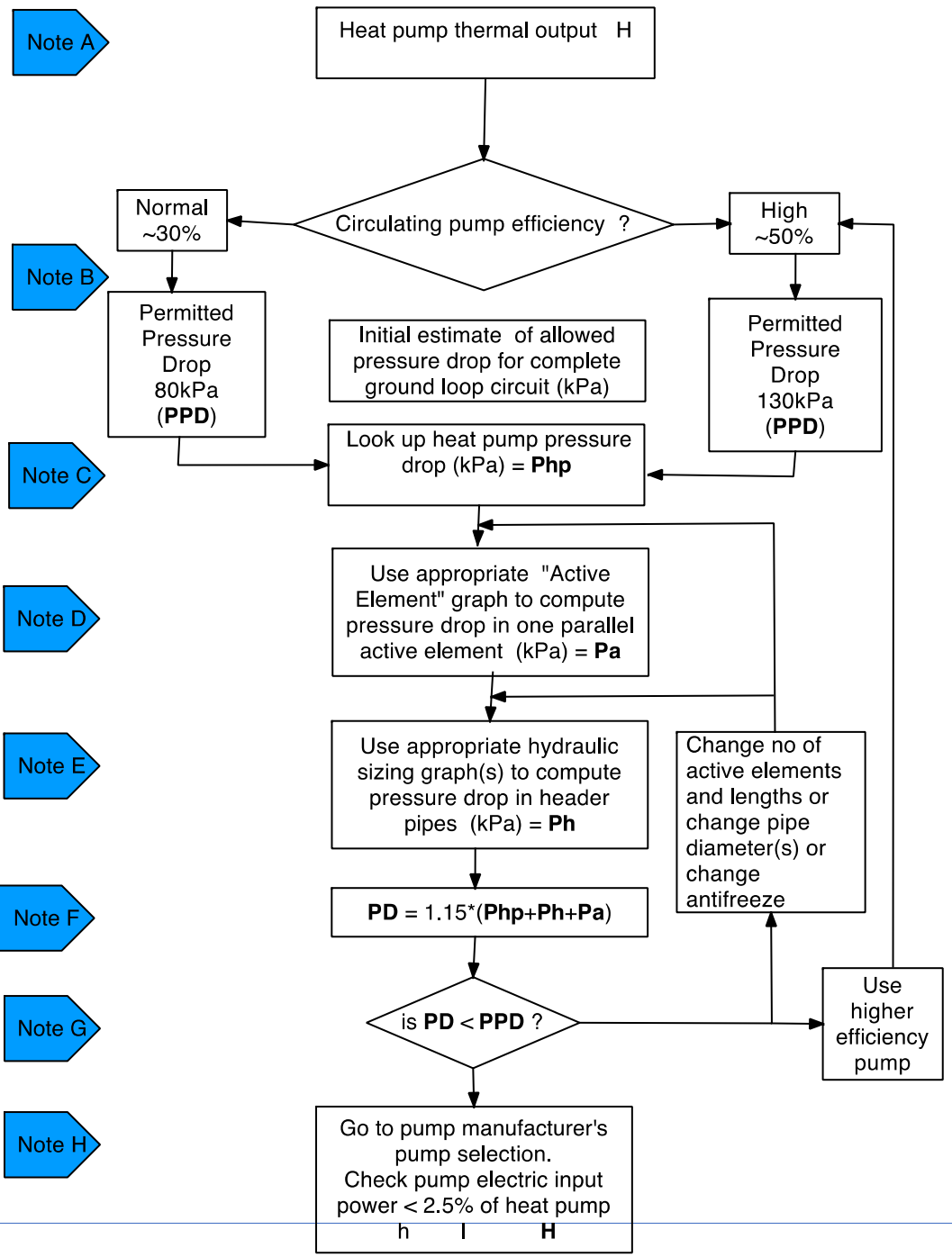
GSHP association

# Hydraulics - the variables

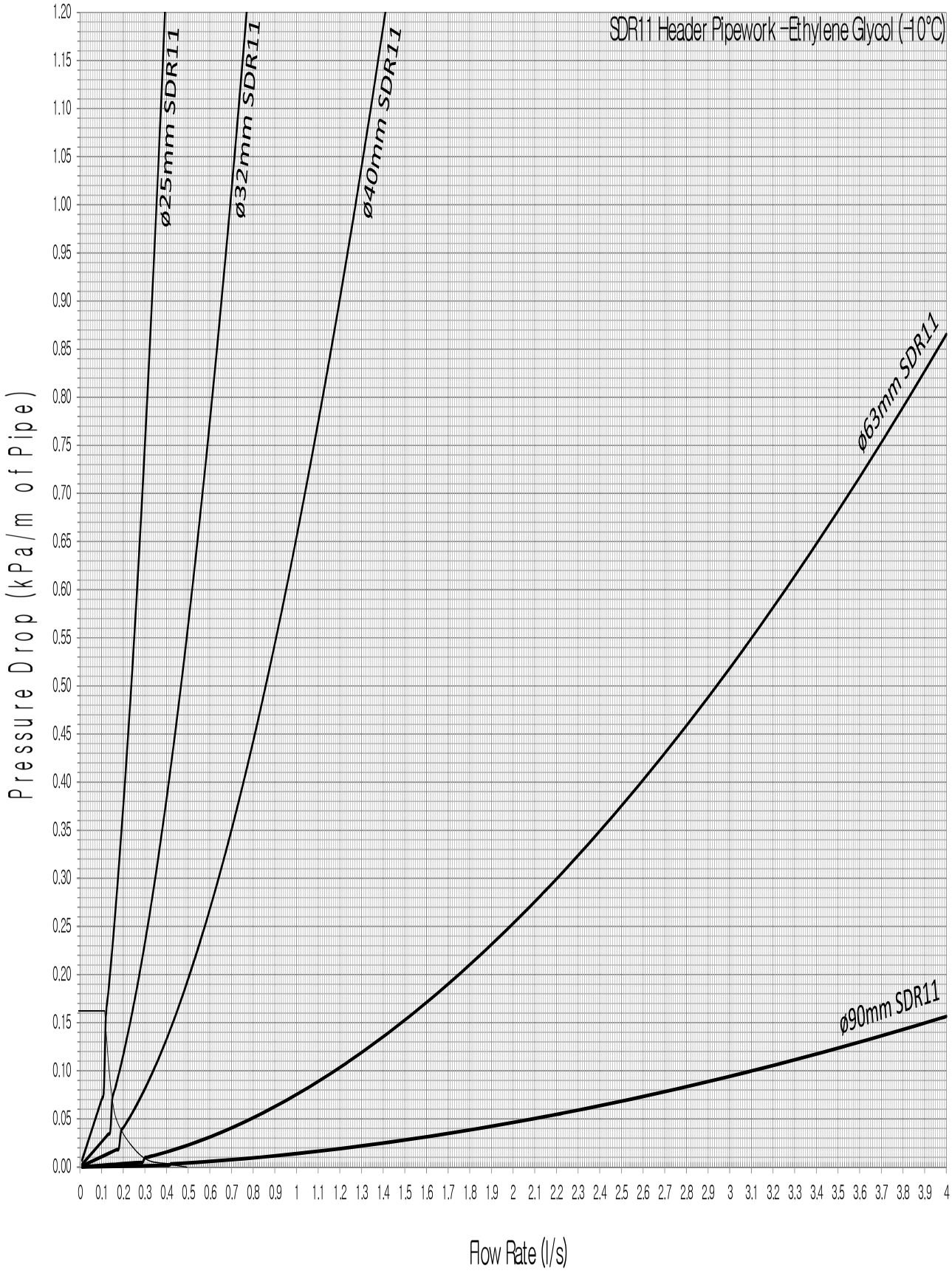
- Borehole/loop lengths vs number
- Pipe diameter
- Borehole pipe configuration (1U / 2U)
- Header arrangements

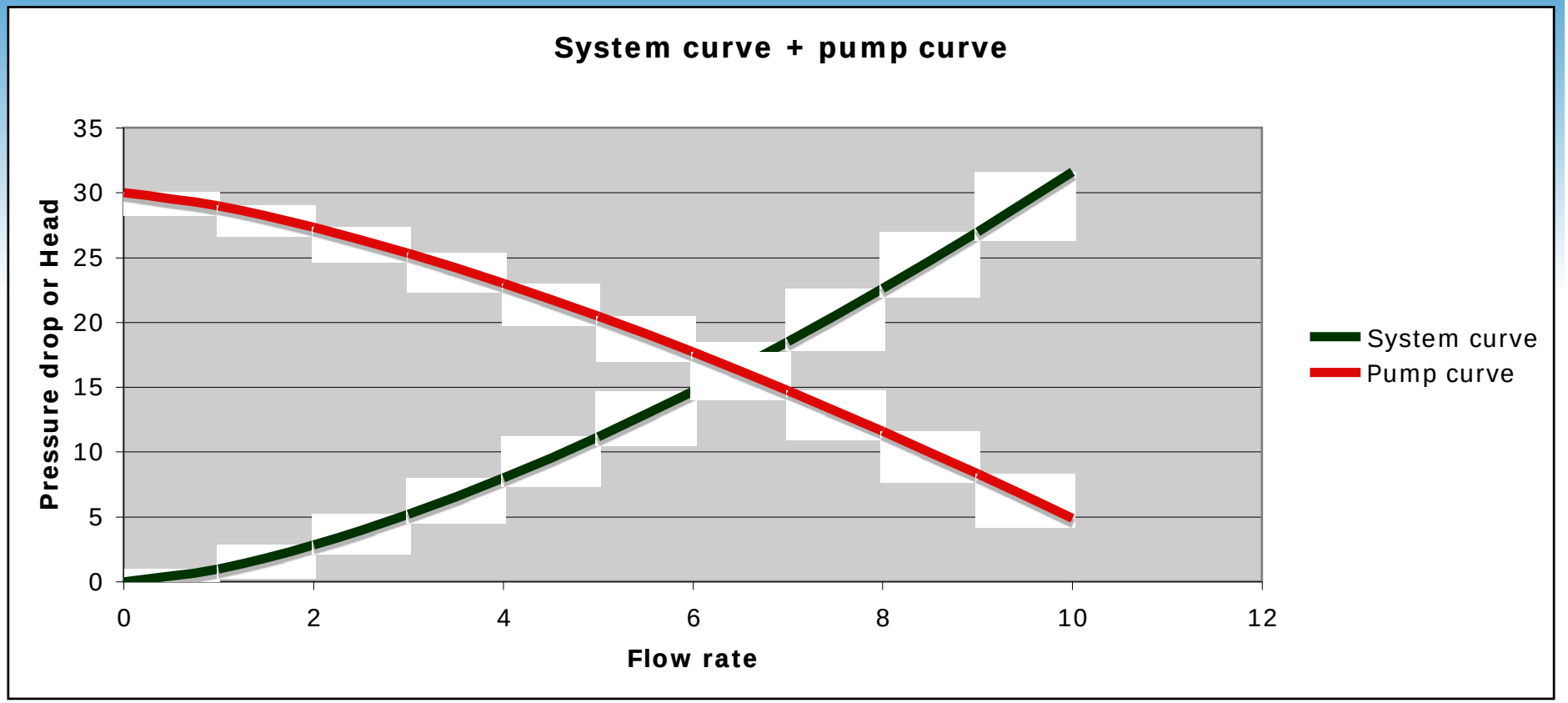
GSHP association

# Closed loop GSHP Hydraulic Sizing Flow Chart




GSHP association


SDR11 Header Pipework – Ethylene Glycol (-10°C)
Pressure Drop (kPa/m of Pipe)
Flow Rate (l/s)
ø25mm SDR11
ø32mm SDR11
ø40mm SDR11
ø63mm SDR11
ø90mm SDR11
1.20
1.15
1.10
1.05
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2 2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8 2.9 3 3.1 3.2 3.3 3.4 3.5 3.6 3.7 3.8 3.9 4




GSHP association

The deliverables:

1) flow charts

2) pressure drop charts

3) accompanying design guide

for: 2 pipe types
2 antifreezes
2 freeze protection limits
@ various pipe diameters

GSHP association

Links to all of these resources are given in the paper.

Methodology should be applicable to any other country / region.(?)

Awaiting incoming criticism /comment/exocets >

>>>>  Revision / update

GSHP association

# OUTCOME ?

GSHP association

But – if you want to get more advanced……

listen in……

- Thank you.

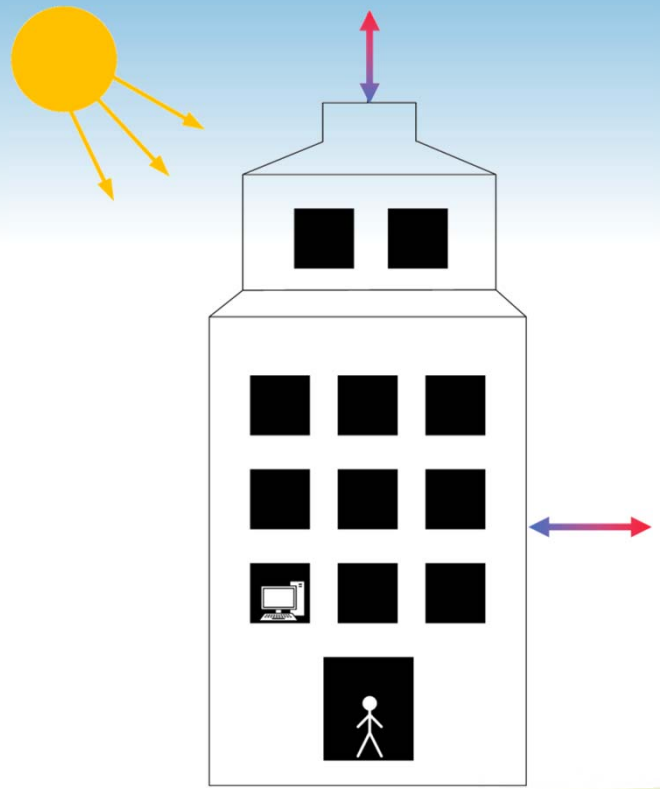
GSHP association

# Ground Loop Design

& the limits of MIS 3005

GSHP association

# The Many Faces of Building Loads



GSHP association

# Design Day vs Monthly Loads

| | Cooling kW | Heating kW |
|---|---|---|
| 0800-1200 | 0 | 142.0 |
| 1200-1600 | 0 | 59.7 |
| 1600-2000 | 0 | 59.7 |
| 2000-0800 | 0 | 59.7 |
| EqFLH | 0 | 2,896 |

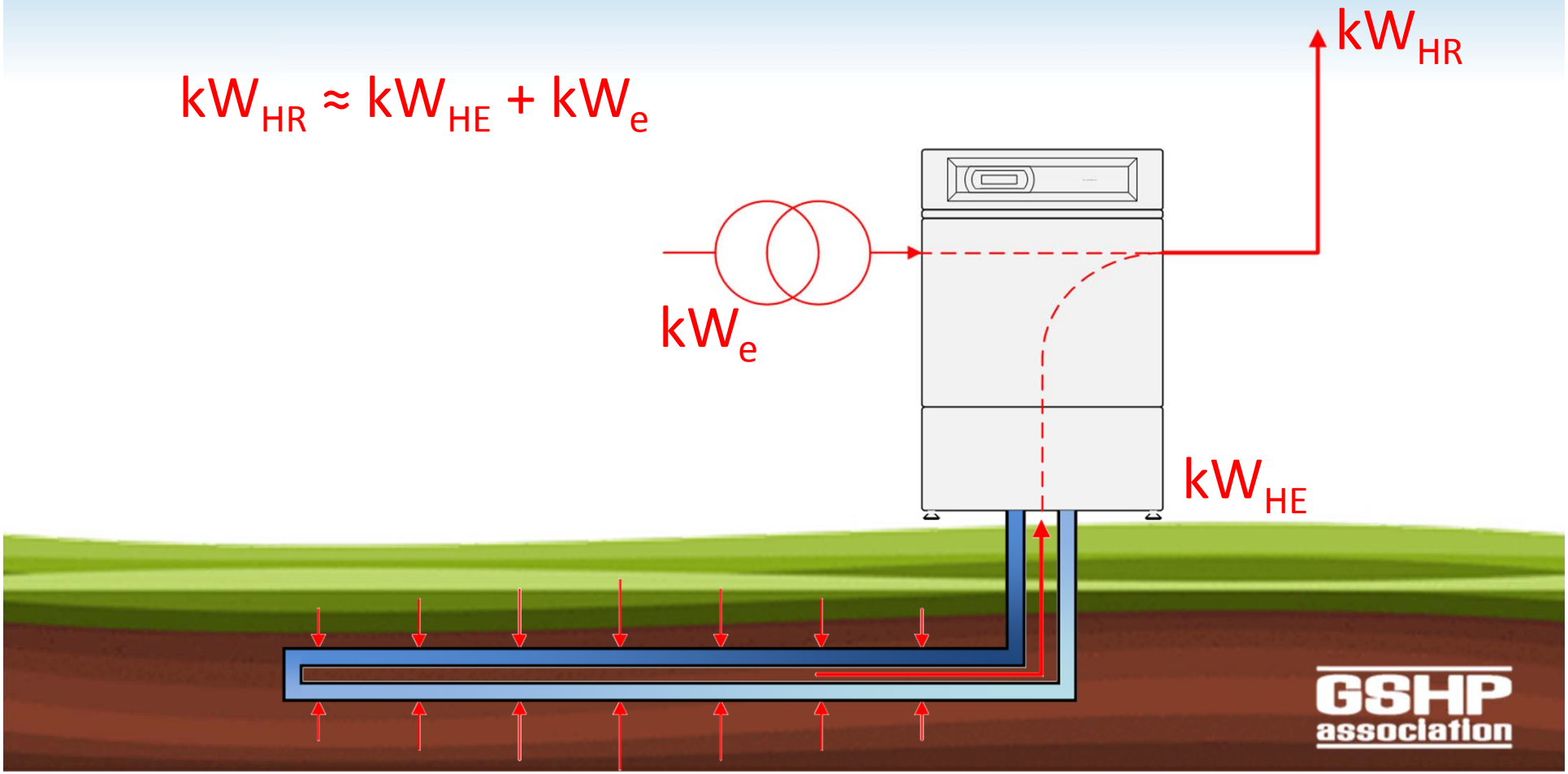
| | Heat Gains | | Heat Losses | |
|---|---|---|---|---|
| Month | Total kWh | Peak kW | Total kWh | Peak kW |
| Jan | 0 | | 54,628 | 142 |
| Feb | 0 | | 52,137 | |
| Mar | 0 | | 48,869 | |
| Apr | 0 | | 40,931 | |
| May | 0 | | 28,791 | |
| Jun | 0 | | 19,141 | |
| Jul | 0 | 0 | 13,693 | |
| Aug | 0 | | 14,160 | |
| Sep | 0 | | 18,207 | |
| Oct | 0 | | 29,258 | |
| Nov | 0 | | 41,242 | |
| Dec | 0 | | 49,491 | |

GSHP association

# Then the Heat Pumps

$COP = kW_{HR} / kW_e$

$kW_{HR} \approx kW_{HE} + kW_e$




GSHP association

# Heat Pump Properties

**MIS 3005**

- Assumes you calculate the COP at the design condition and apply that to the building load
- So it returns Heat of Extraction
- No corrections for flow rates

**Design Software**

- Holds data for,
  - Source temperatures
  - Load temperatures
  - Source flow corrections
  - Load flow corrections
  - Heat Pump limits
- Extrapolates & Interpolates from published data

GSHP association

# Ground Conditions

**MIS 3005**

- Inputs,
  - Undisturbed Ground Temperature
  - Conductivity
- Fixed,
  - Diffusivity

**Design Software**

- Inputs,
  - Undisturbed Ground Temperature
  - Conductivity
  - & Conductivity Averager
  - Diffusivity
  - & Diffusivity Averager
  - TRT Data & Processing

GSHP association

# Pipes & Pumps

**MIS 3005**

- Basically all fixed,
  - 130mm bores
  - 32mm pipes
  - 25% MEG
  - Limited horizontal options
  - Turbulent
  - 2.4 W/mK grout

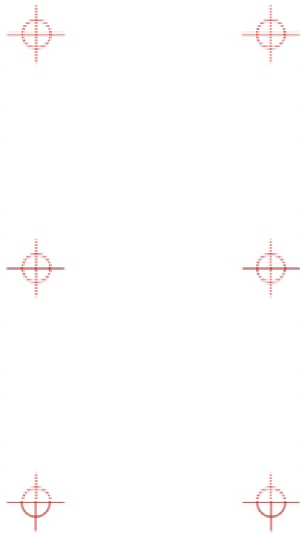
**Design Software**

- Inputs,
  - Circulation Pump Loads
  - Fluid Properties
  - Pipe Diameter
  - Placement in Bore
  - Horizontal geometries
    - 6 pipe, 4 pipe etc
  - Grout properties
  - Flow Conditions
    - Laminar - Transition - Turbulent

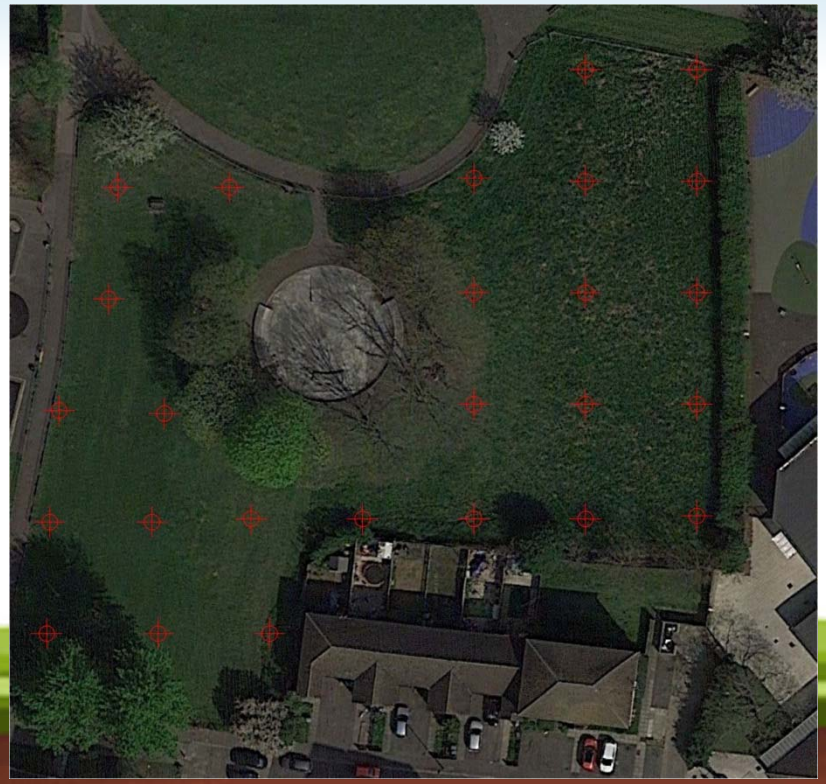
GSHP association

# Borehole Locations

**In MIS 3005 World**



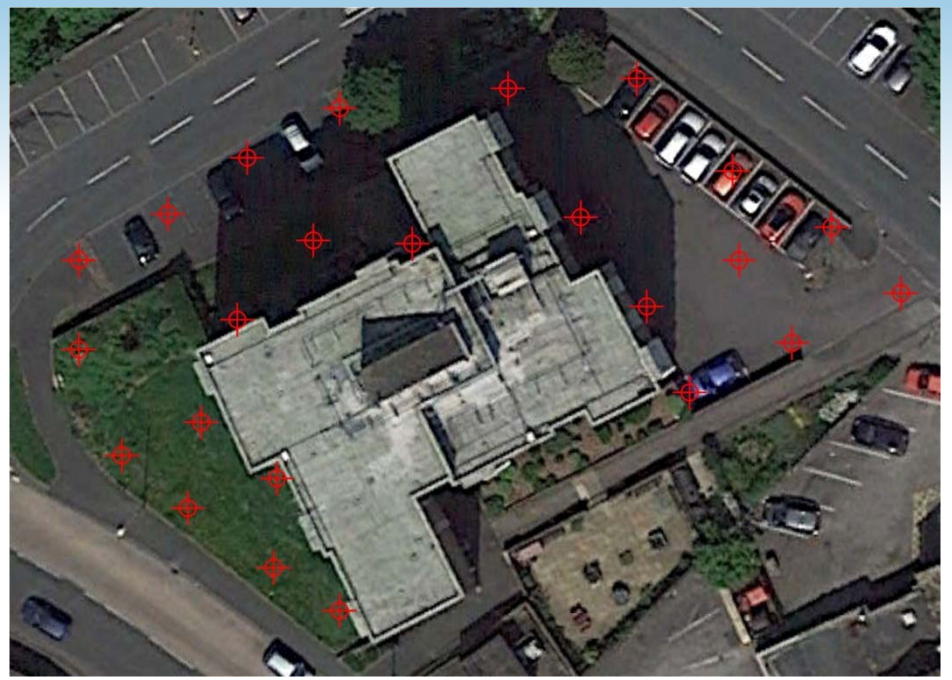
**In the Real World**



GSHP association

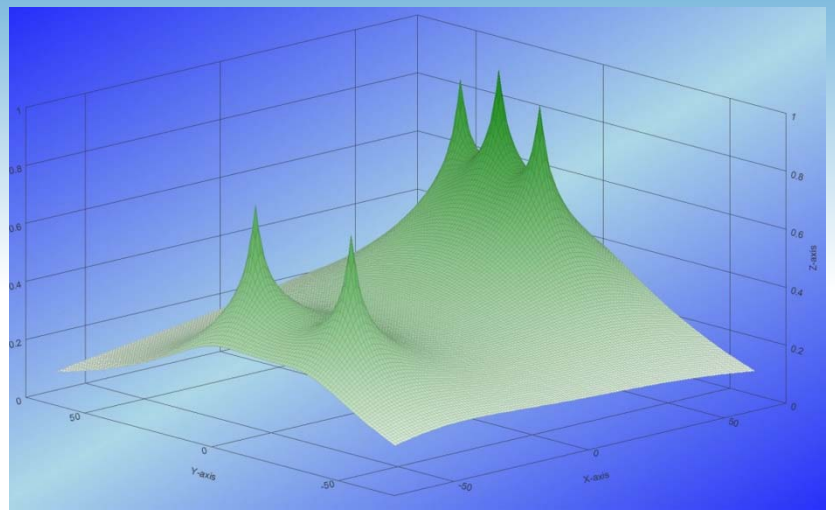
# The Effect….

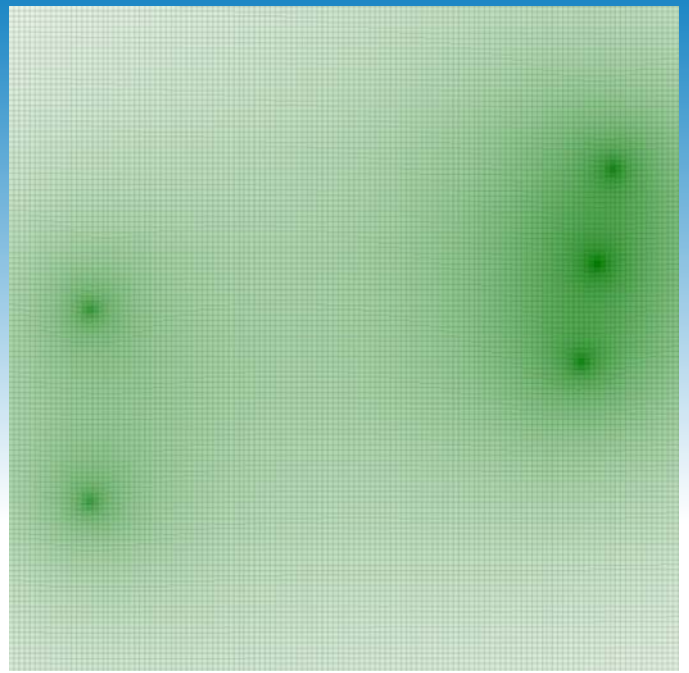
- Block of Apartments
- 142 kW, 2,896 EqFLH
- MIS 3005
  - 24 x 169m
  - 6m spacing
- Actual Design
  - 24 x 193m
  - See layout right
  - BUT it will work!

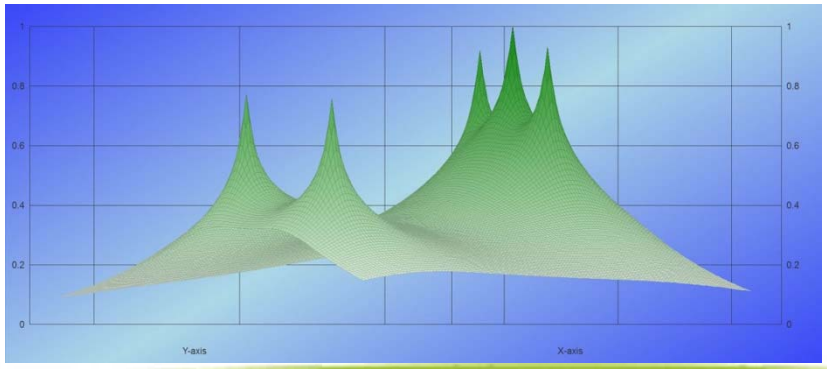


GSHP association

# The Effect….






GSHP association

# Take Away Messages….

- Exceptions to the MIS 3005 tables do exist
- Know the limits of look-up table “design”
- Look out for the warning signs
- Pipe is cheap!
- Keep your spacings up – Borehole & Slinky Pitch
- Consider further training
- *Please, Please, Please ask for help*

GSHP association