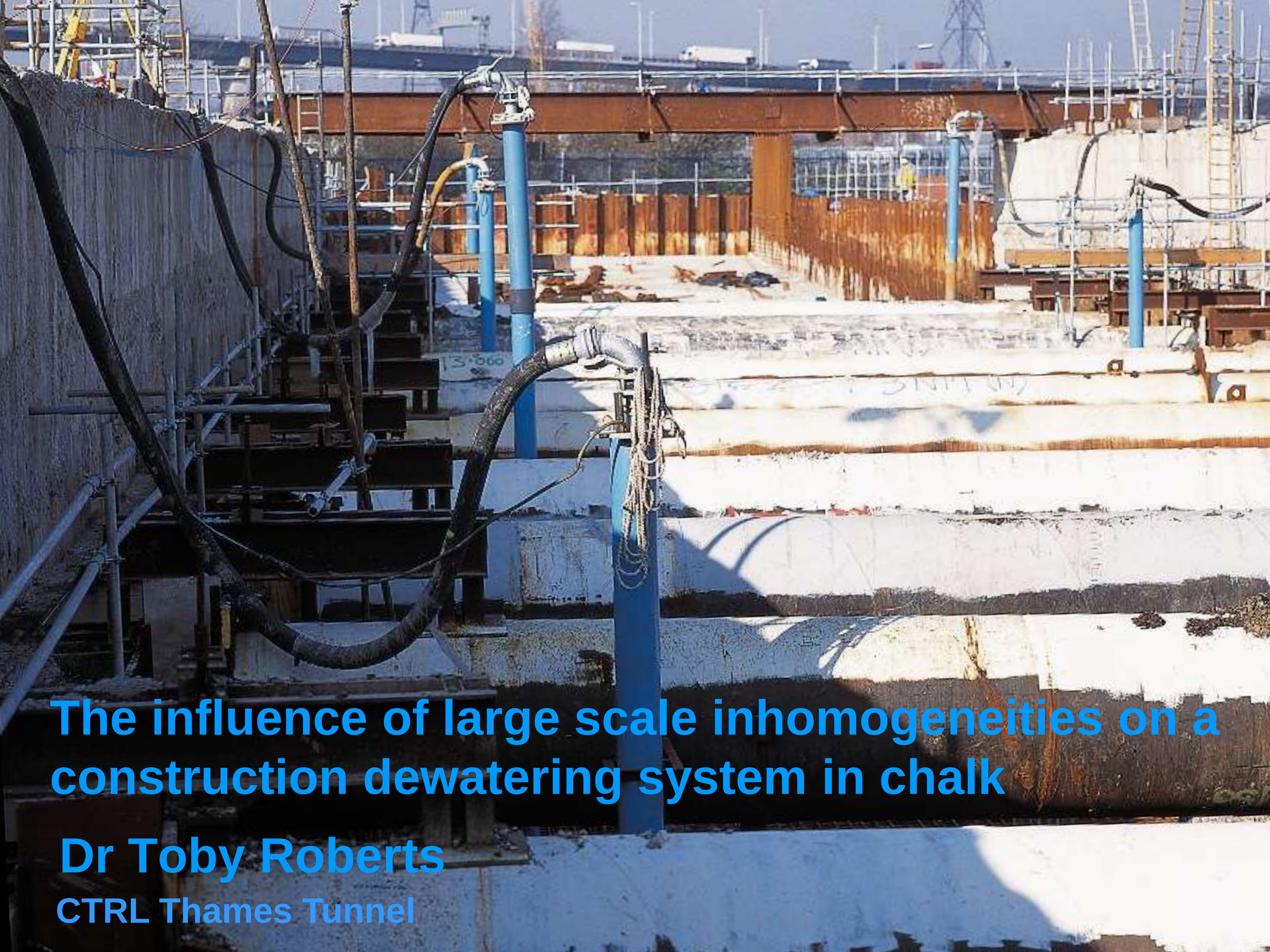


The influence of large scale inhomogeneities on a construction dewatering system in chalk

Dr Toby Roberts
CTRL Thames Tunnel

CTRL 320 Thames Tunnel (£133M)

Twin 2.5 km 7.15 m diameter bored tunnel beneath River Thames. Dewatering required for approach structures, 400 m by 28 m in plan by up to 18 m below groundwater level.

Project Management: RLE

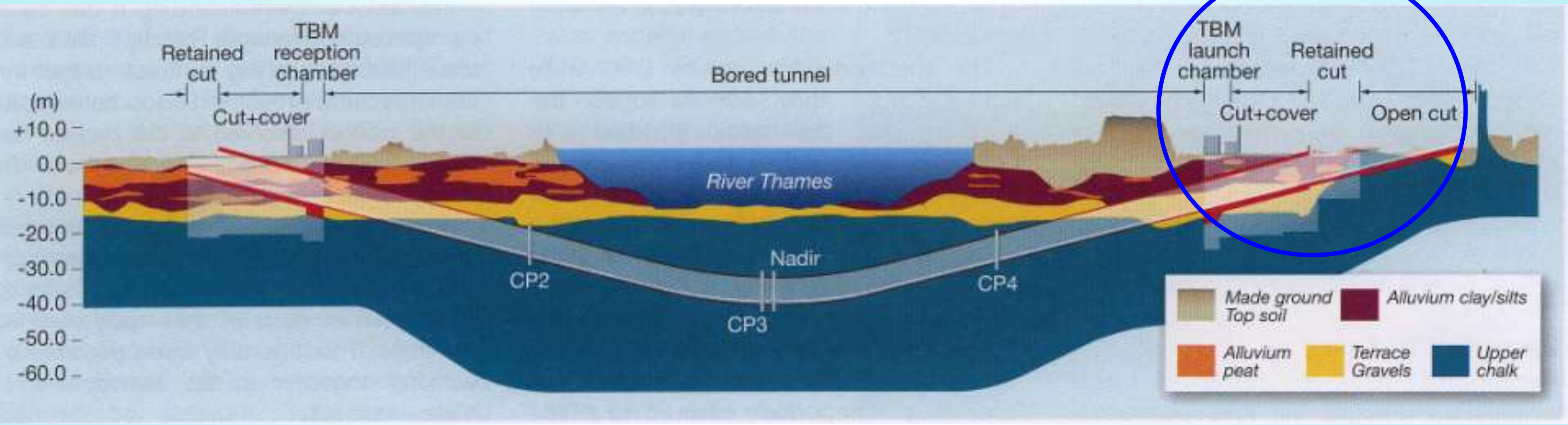
(Arup Bechtel Halcrow SYSTRA)

Main Contractor: HOCHTIEF MURPHY JV

Dewatering: WJ GROUNDWATER LTD


CTRL Thames Tunnel – dewatering for approach structures
Tank farm
Northern approach
Tunnels
Southern approach

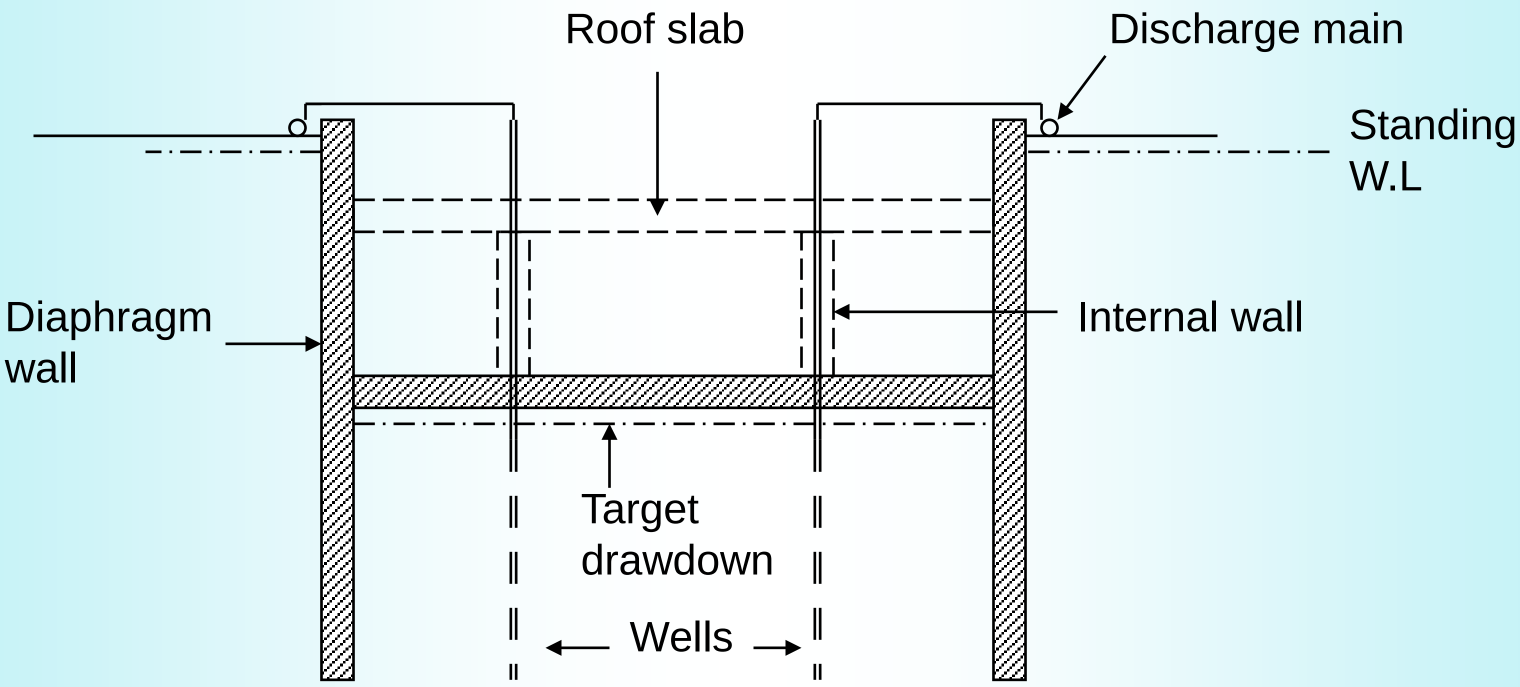
Southern approach

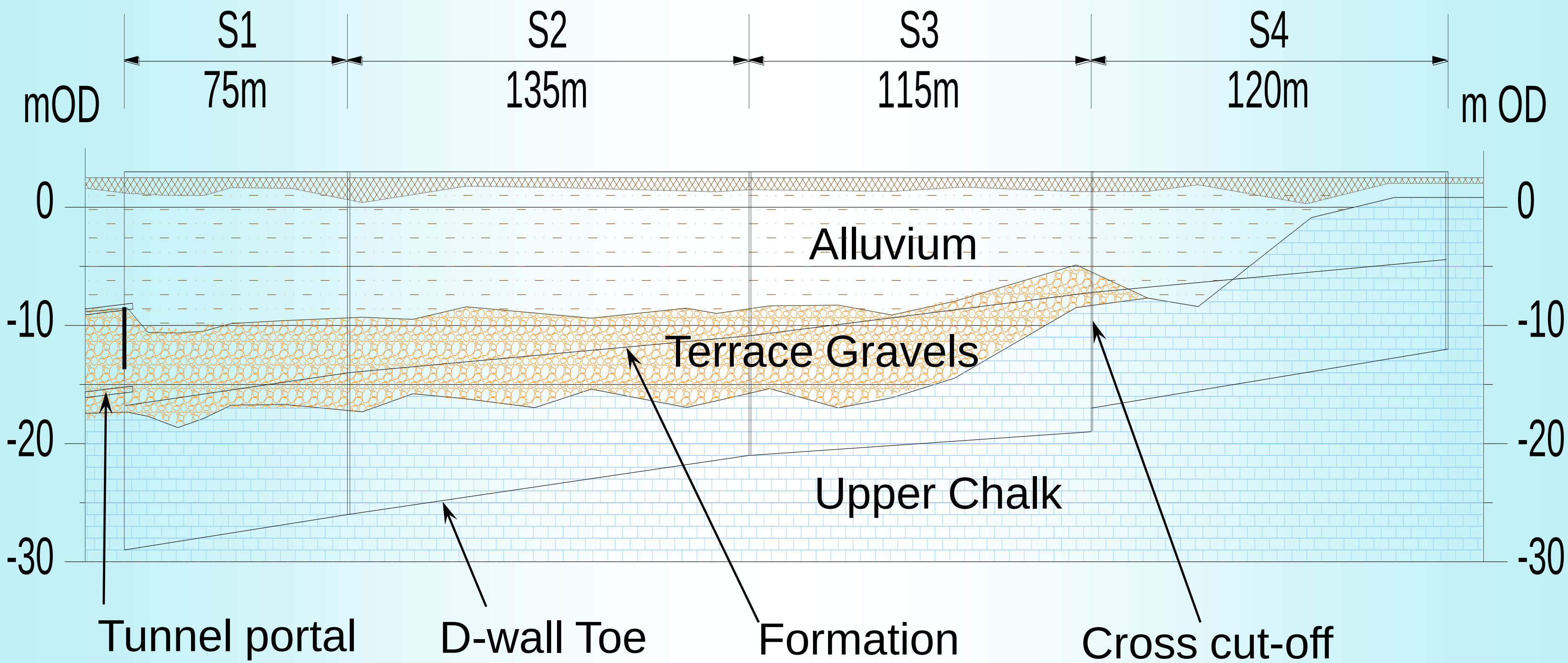


Longitudinal Tunnel Section

CTRL Thames Tunnel

Cross-section
of approach

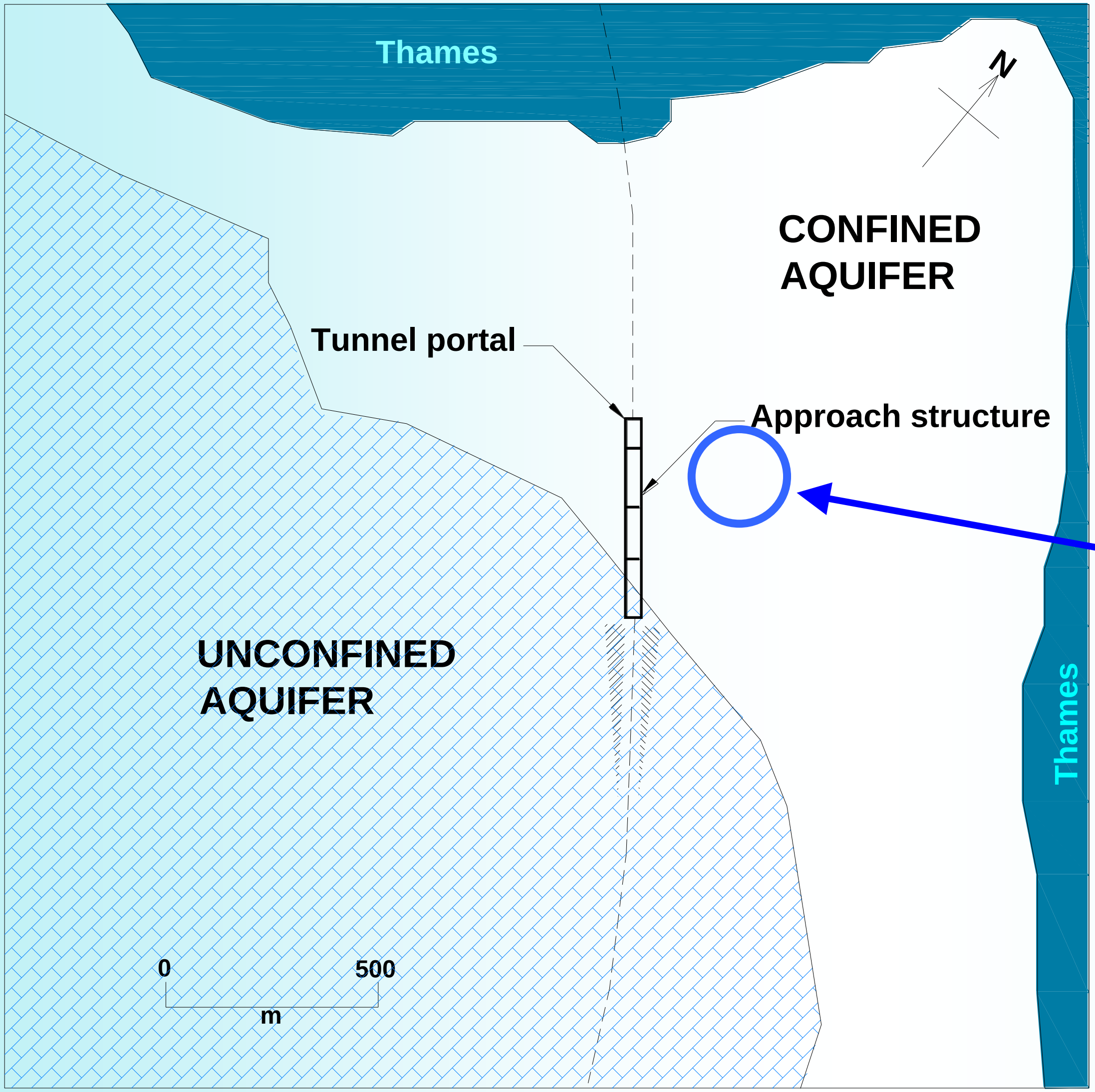




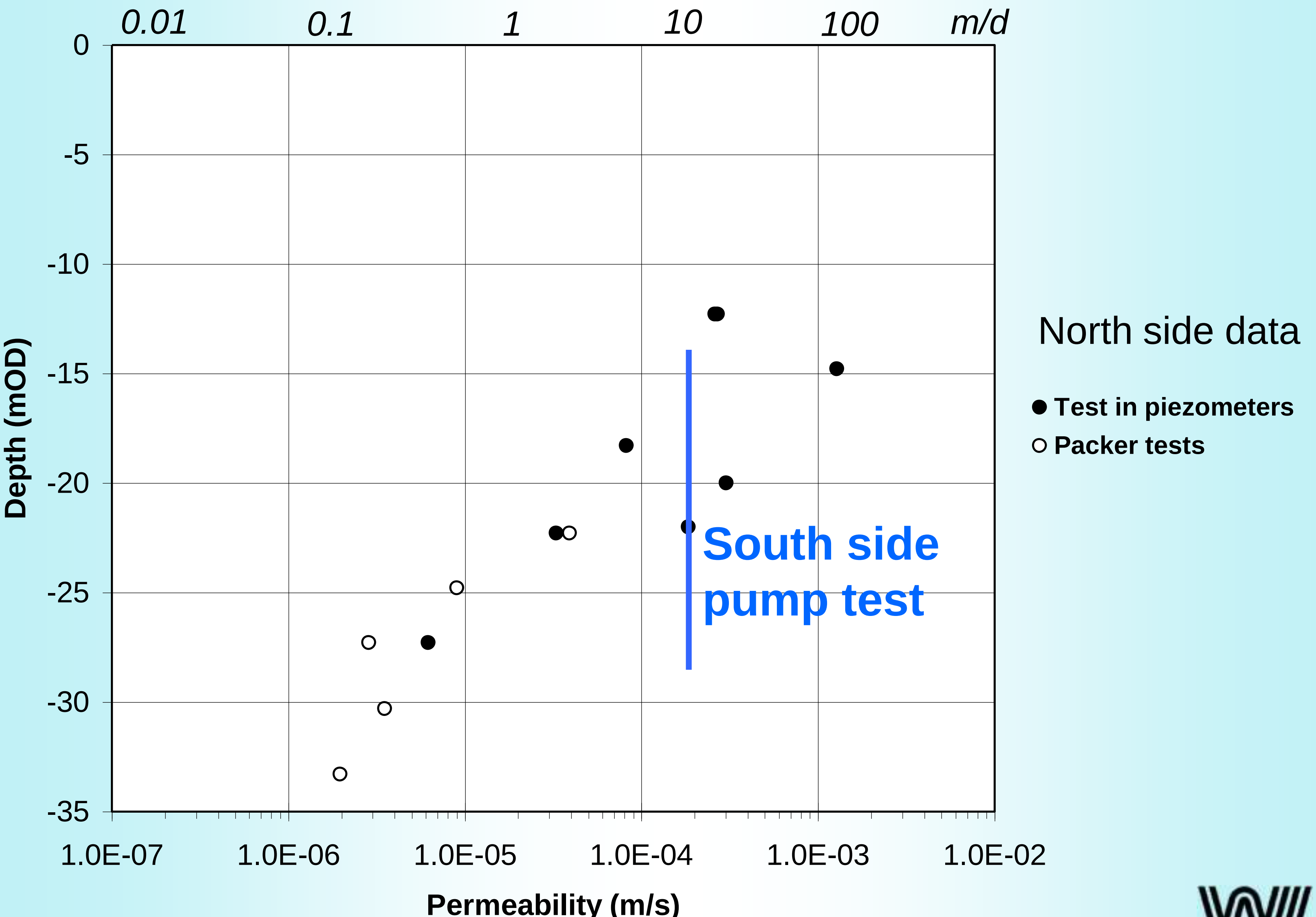
- Dewatering of a 445 m x 28 m structure with side support by diaphragm walls, divided into 4 sections (S1 to S4)
- Formation level from 18 to 6 mbgl

Southern Approach Geological Section

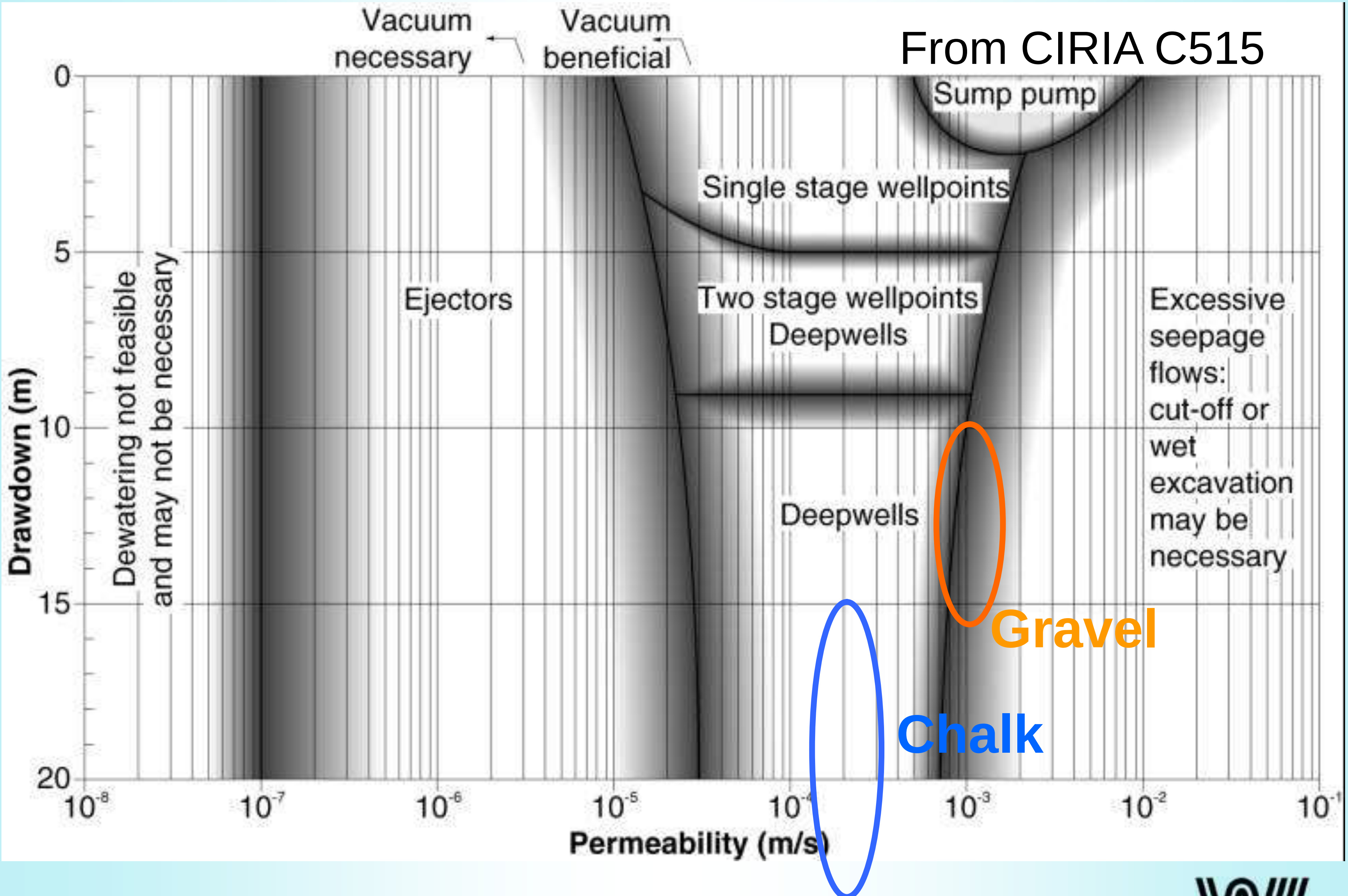
The extent of the Chalk outcrop



Pump test location



Chalk permeability depth profile



Range of application of dewatering techniques

Design Information:

Pumping Test: Terrace Gravels $k = 3 \times 10^{-3}$ m/s *260 m/d*

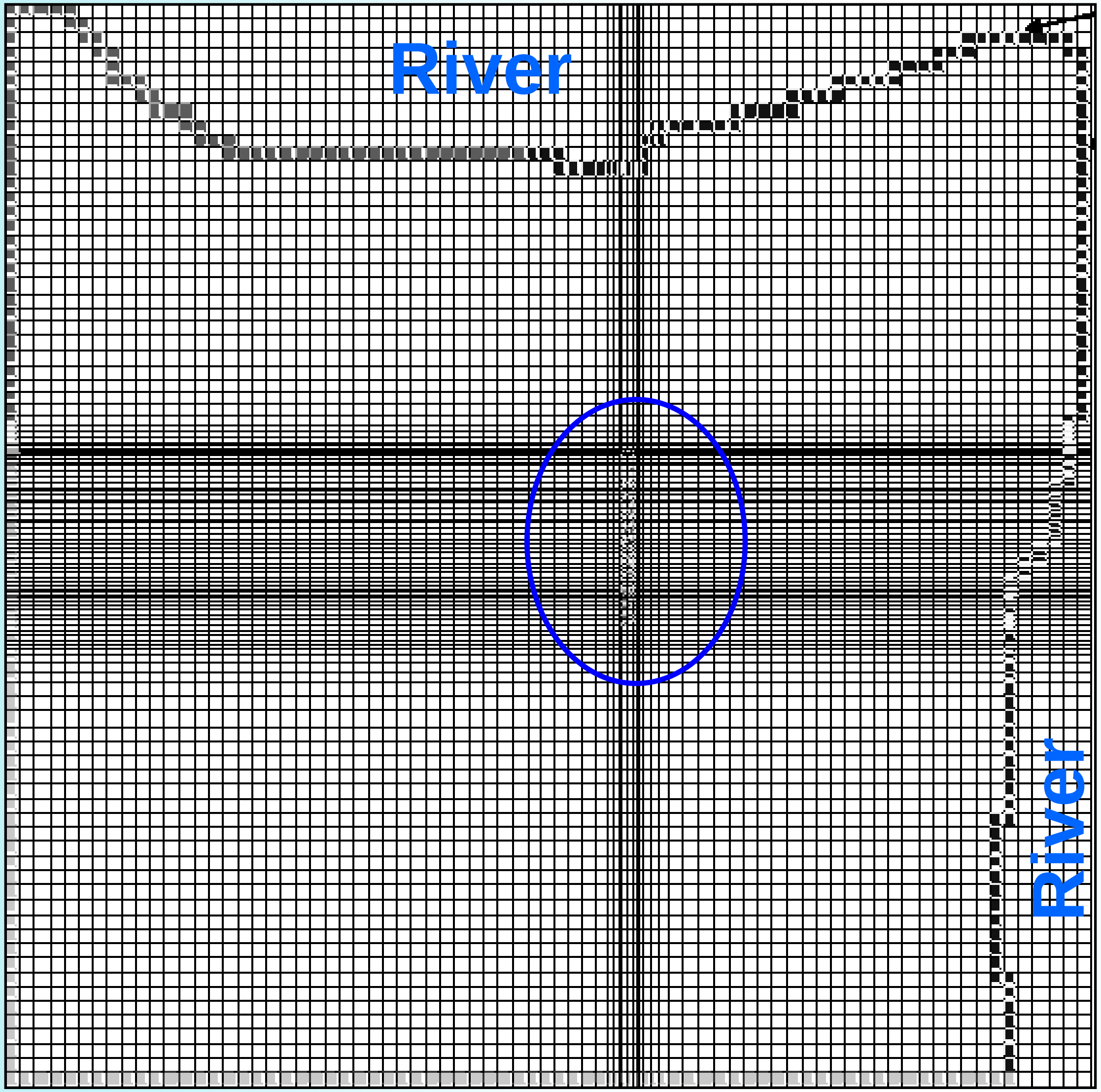
Pumping Test: Chalk: $k_h = 2 \times 10^{-4}$ m/s *17 m/d*

Packer Tests (North Side) – Chalk *k* decreases with depth

Conventional wisdom suggests former spring line and elevated *k* zone along line of Chalk outcrop (cut-off?)

Design Basis:

Terrace Gravels	$k_h = k_v = 3 \times 10^{-3}$ m/s	260 m/d
Chalk	$k_h = k_v =$ **2×10^{-4} m/s**	**17 m/d**



3D Numerical model:

Used as design basis

Used to consider interaction between sections

Used for sensitivity analysis

Used to look at hydrostatic load on D-wall

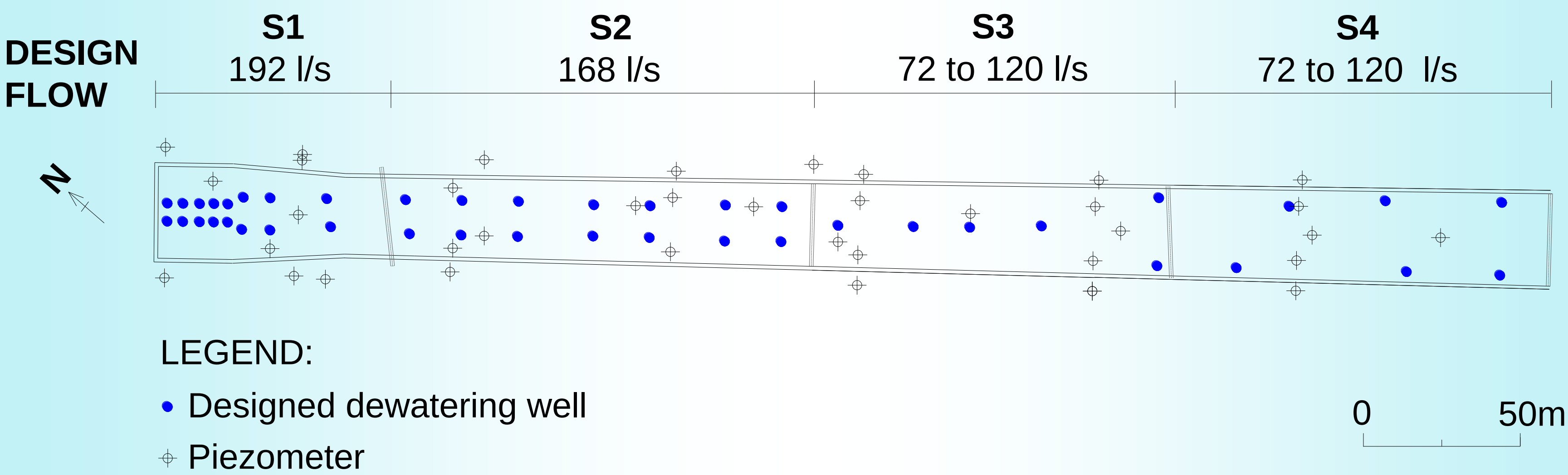
MODFLOW finite difference grid

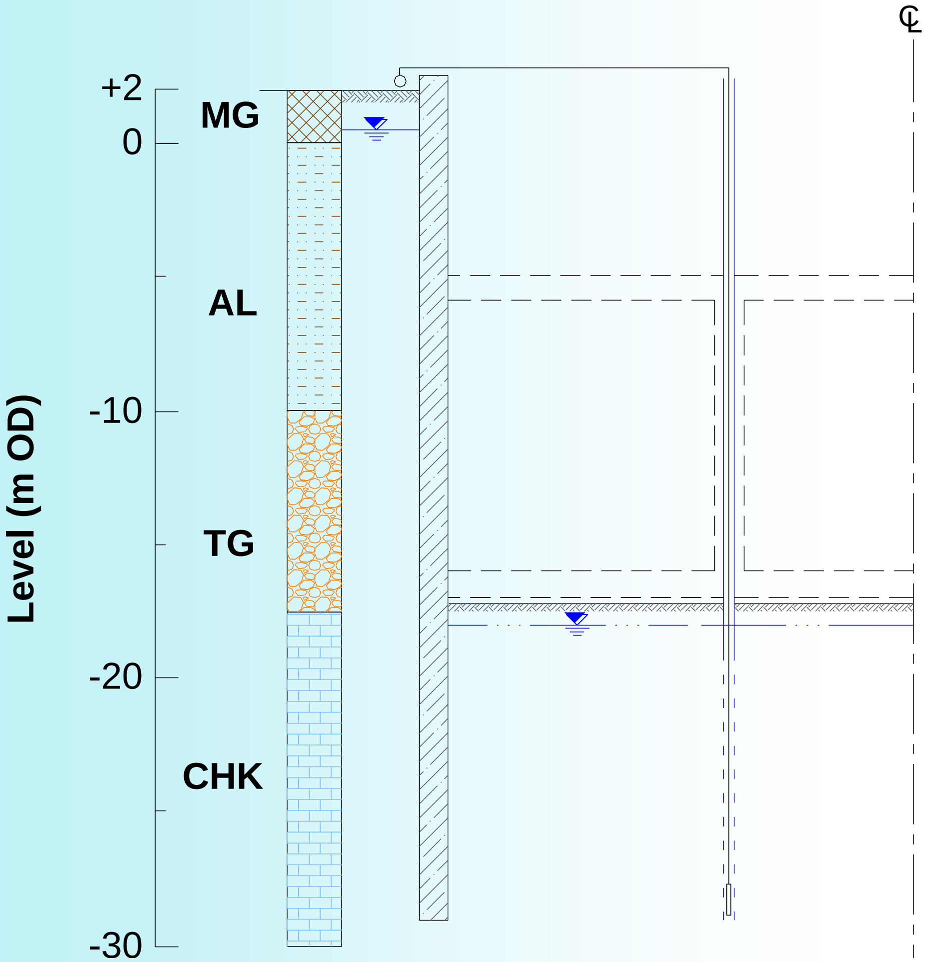
Dewatering Scheme Design

Section	S1	S2	S3	S4
Length (m)	75	135	115	120
Dig depth (mOD)	-17	-14	-11	-7
Design flow (l/s)	**192**	**168**	**72/120**	**72/120**
No. of wells (12 to 20 l/s)	16	14	6	6

Total design flow: **600 l/s**

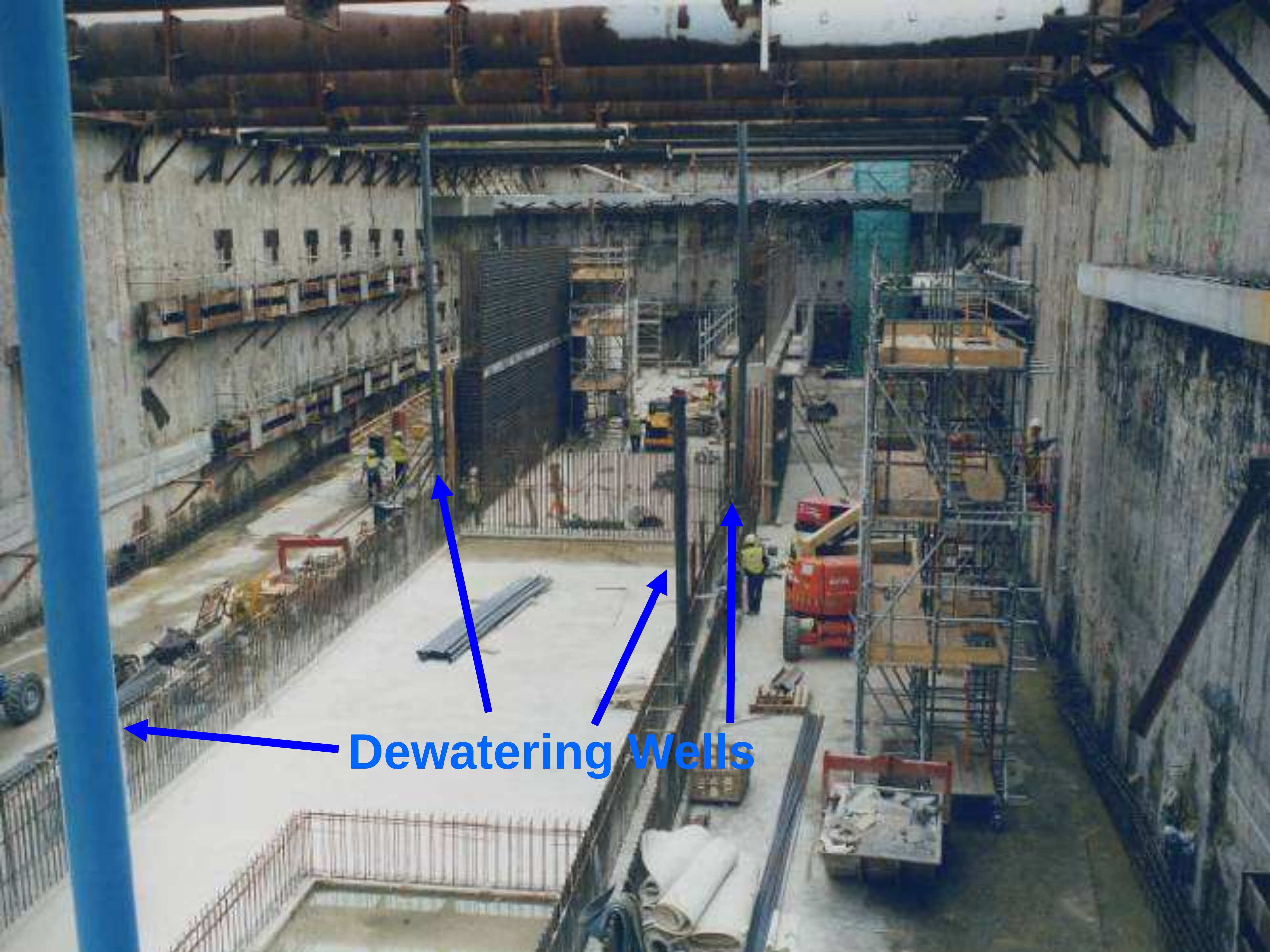
Total No. of wells: 42 No.


DESIGN FLOW
S1
192 l/s
S2
168 l/s
S3
72 to 120 l/s
S4
72 to 120 l/s
N
LEGEND:
Designed dewatering well
Piezometer
0
50m

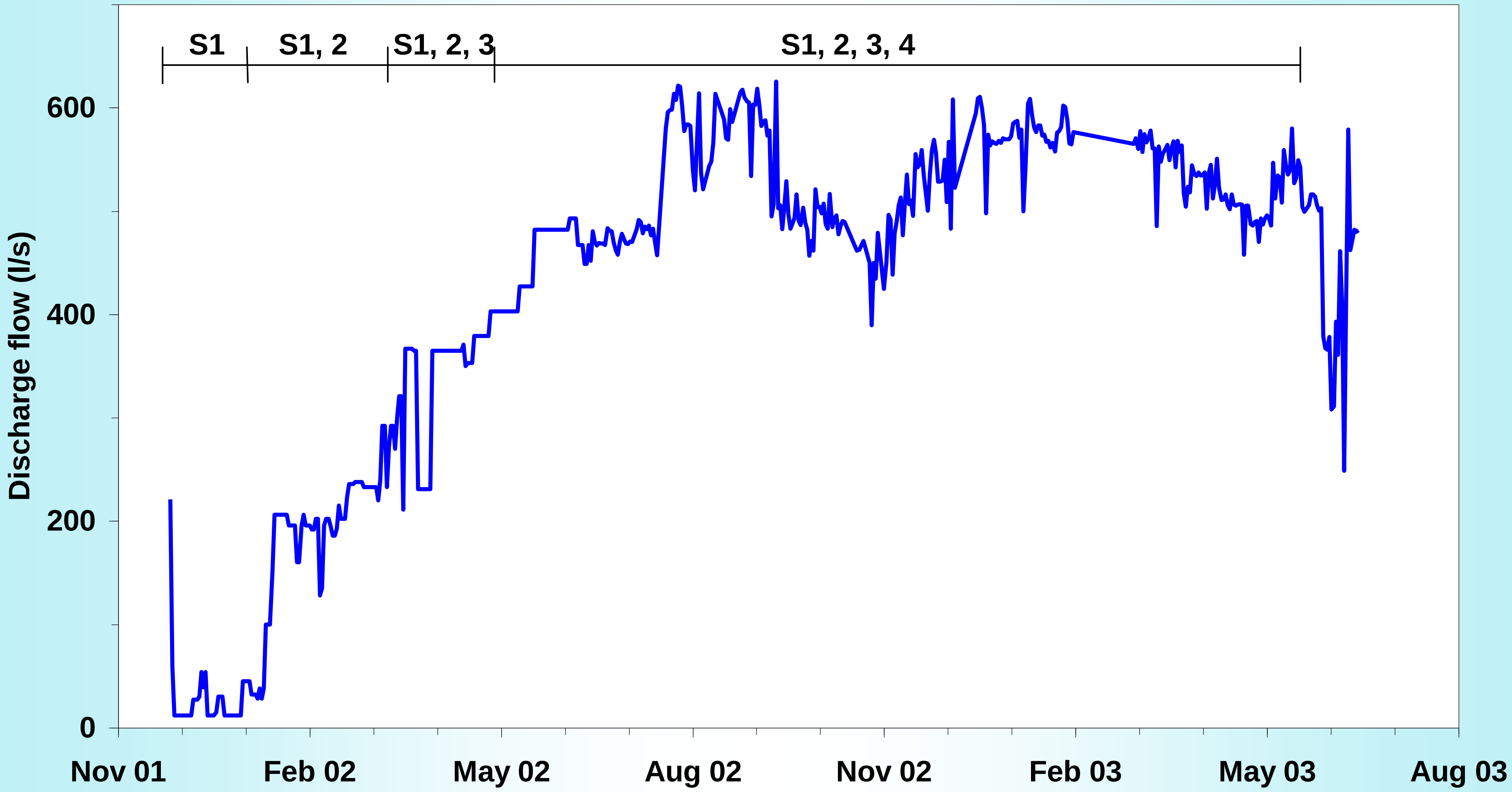


Internal deepwell dewatering system

Aerial view of southern approach structure (Excavation in S1 and S2 underway)


Dewatering Wells

Water outfalls into the Thames via discharge main

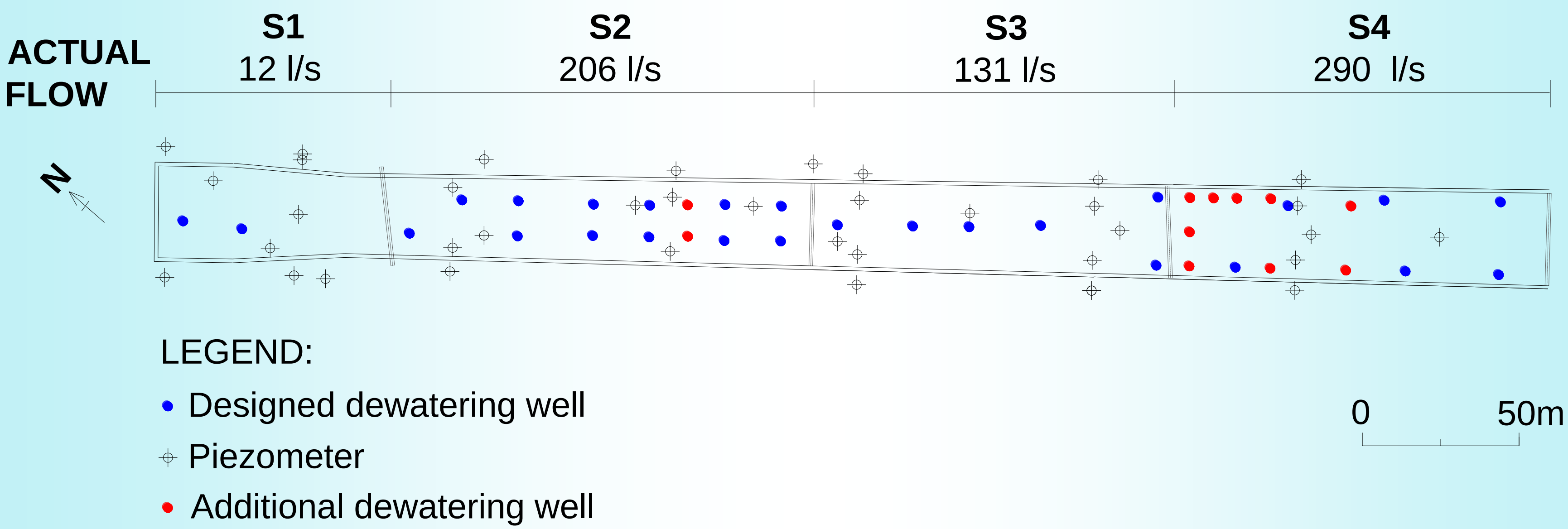


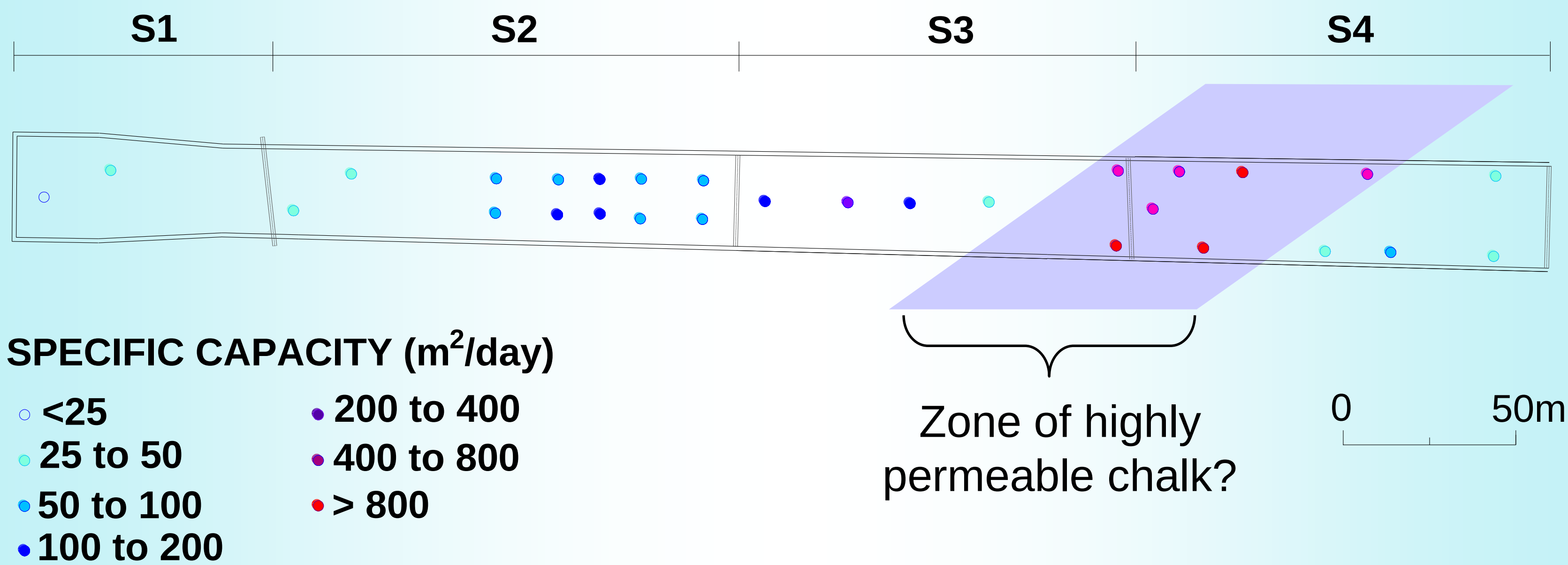
S1
S1, 2
S1, 2, 3
S1, 2, 3, 4
Discharge flow (l/s)
600
400
200
0
Nov 01
Feb 02
May 02
Aug 02
Nov 02
Feb 03
May 03
Aug 03

Flow Record

Comparison between design capacity and actual flows

Section	S1	S2	S3	S4
Length (m)	75	135	115	120
Depth (mOD)	-17	-14	-11	-7
Design flow (l/s)	192	168	72/120	72/120
Actual Flow (l/s)	**12**	**206**	**131**	**243**

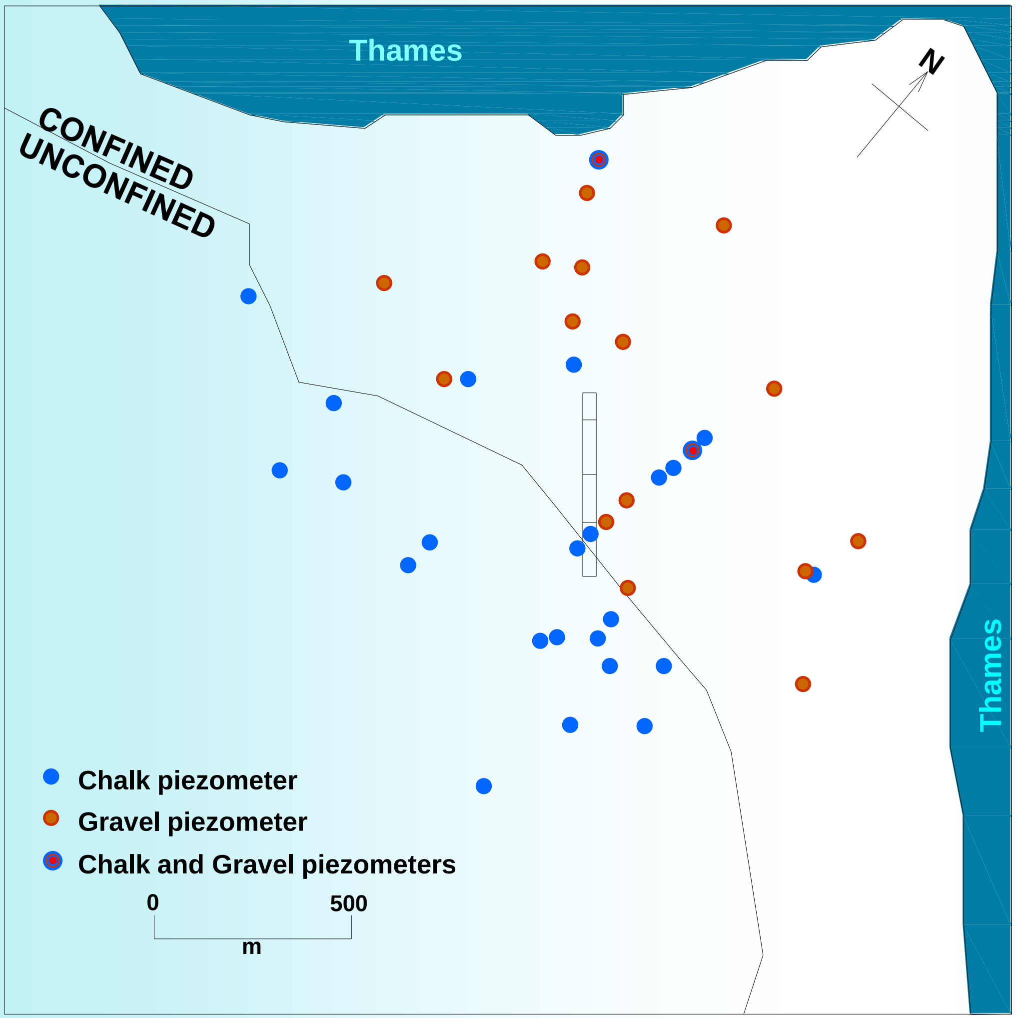

ACTUAL FLOW
S1
12 l/s
S2
206 l/s
S3
131 l/s
S4
290 l/s
N
LEGEND:
Designed dewatering well
Piezometer
Additional dewatering well
0
50m



NOTE: Specific capacity = flow/drawdown

Variation in well performance along approach structure

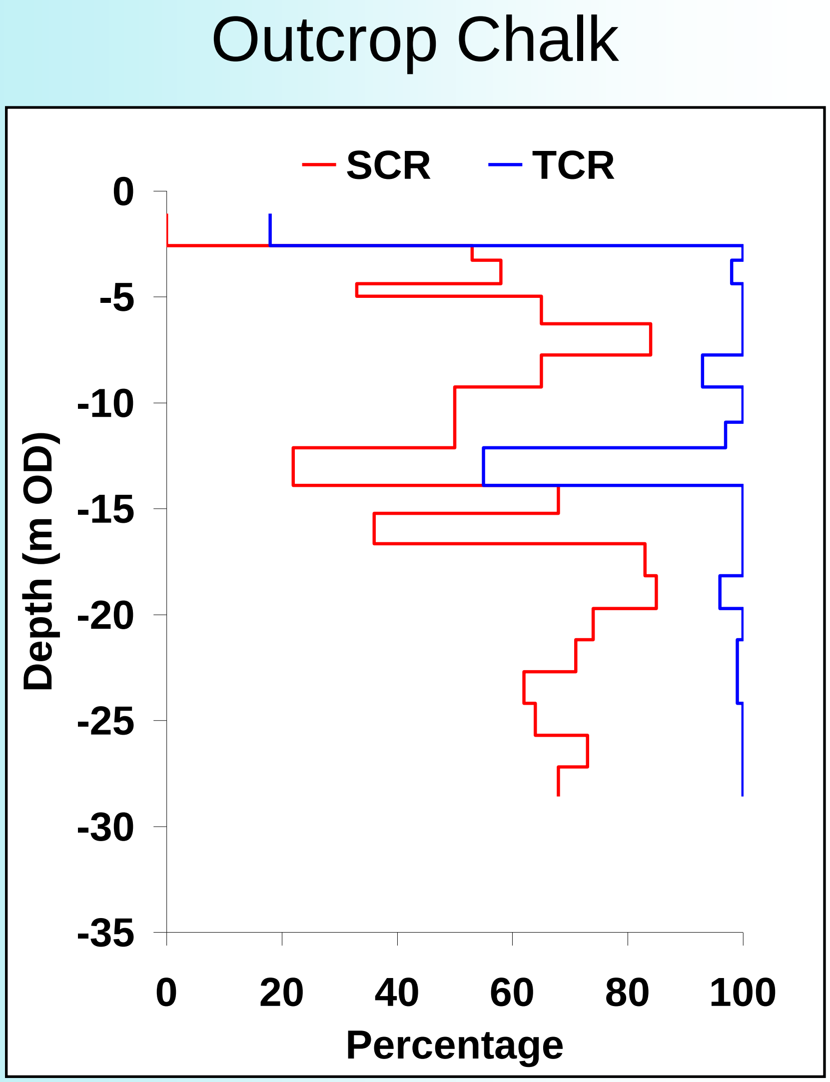

HPZ

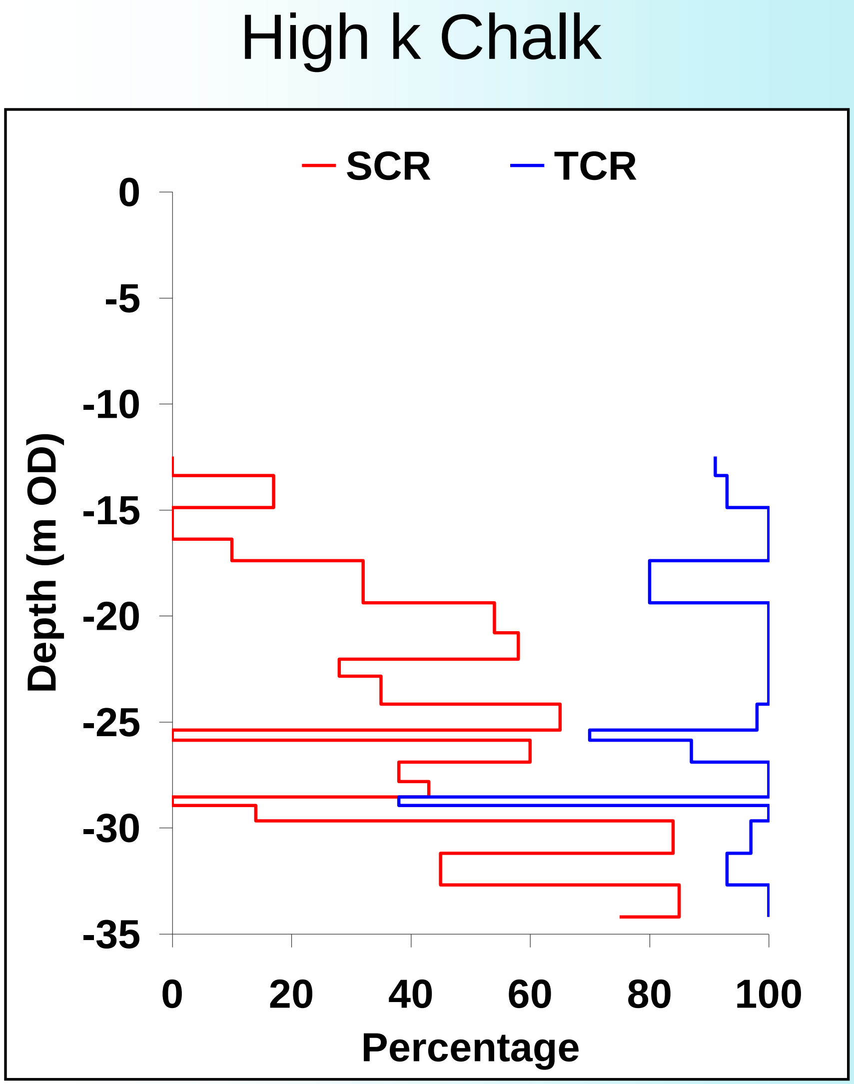


Array of remote standpipe piezometers

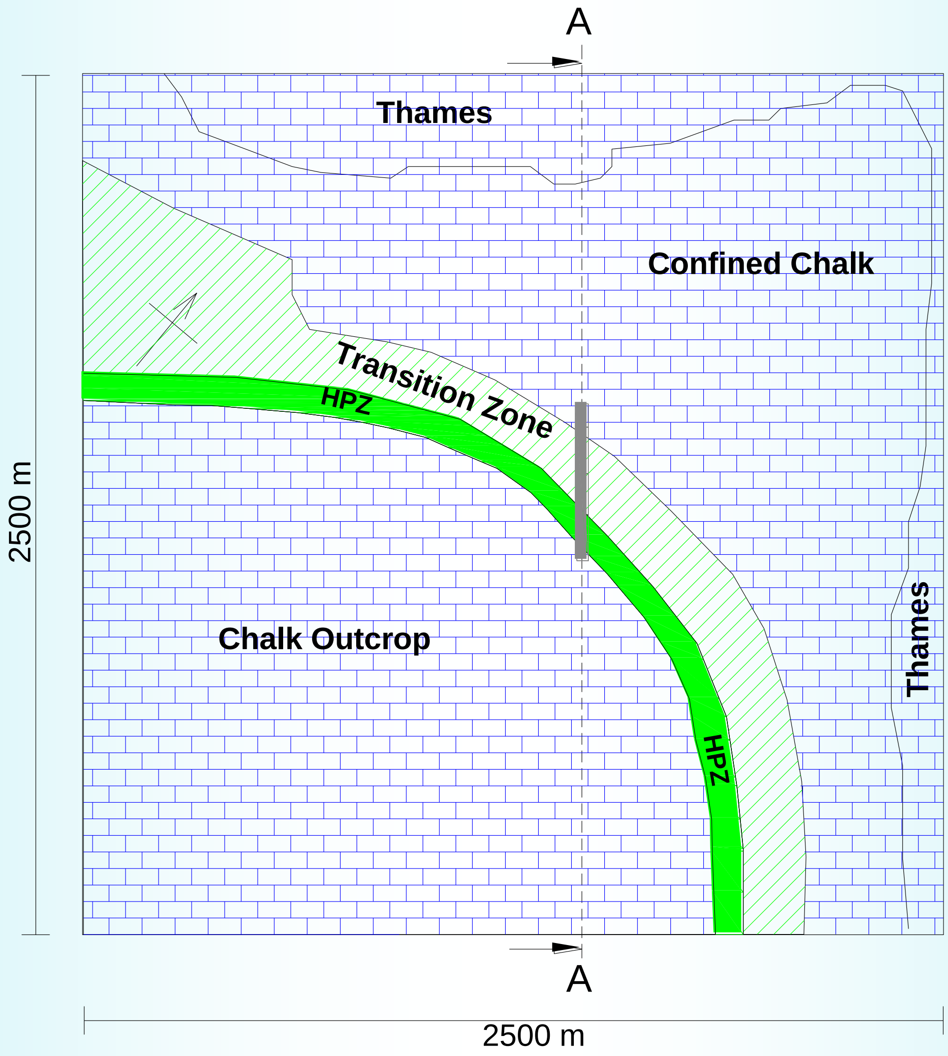
- Tidal fluctuations established prior to start of pumping by datalogging over 24 hr period.

- Manual dipping at weekly to monthly intervals for duration of dewatering

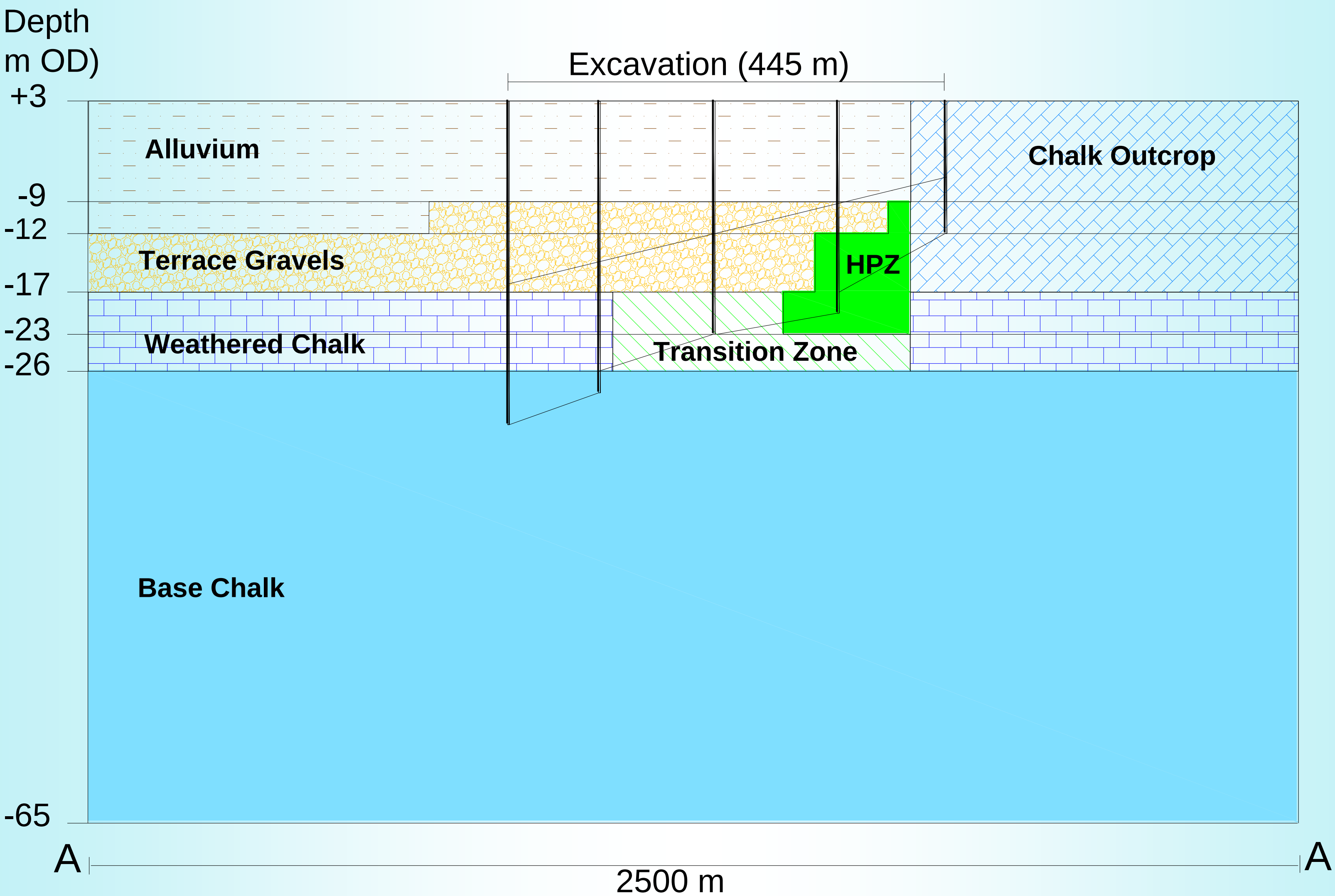




Variation in the quality of cores from the Chalk



Extrapolated size and location of highly permeable zone of Chalk



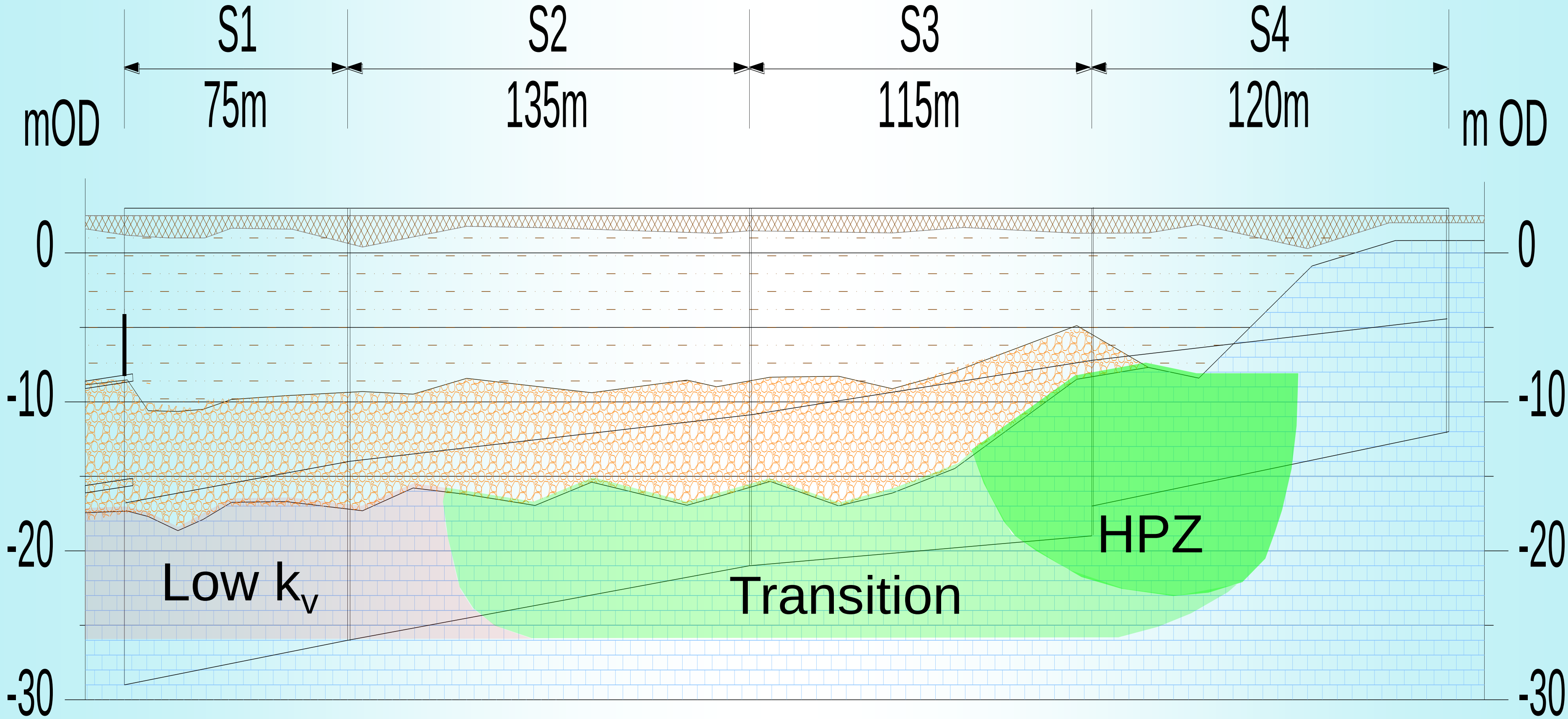
Model section along structure

Design Basis:

Terrace Gravels	$k_h = k_v = 3 \times 10^{-3}$ m/s	*260 m/d*
Chalk	$k_h = k_v = 2 \times 10^{-4}$ m/s	*17 m/d*

Best Fit Model:

Terrace Gravels:	$k_h = k_v = 2 \times 10^{-3}$ m/s	
Chalk Outcrop:	$k_h = 6 \times 10^{-4}$ m/s, $k_v = 6 \times 10^{-5}$ m/s	
High k Chalk:	$\boldsymbol{k_h = k_v = 6 \times 10^{-2}}$ **m/s**	***5,200 m/d***
Transition Zone:	$\boldsymbol{k_h = k_v = 5 \times 10^{-4}}$ **m/s**	***40 m/d***
Weathered Chalk:	$k_h = 4 \times 10^{-4}$ m/s, $\boldsymbol{k_v = 1 \times 10^{-6}}$ **m/s**	***0.09 m/d***
Base Chalk:	$k_h = 2 \times 10^{-5}$ m/s, $k_v = 2 \times 10^{-7}$ m/s	



Southern Approach Geological Section

Observations

- Site investigation did not identify high k zone
- High k zone expected but scale uncertain – cut-off?
- Anisotropic conditions hard to identify in SI
- Coped with 2 orders of magnitude change in k
- Cost/programme impacts modest in this case
- Flow and drawdown data important in early identification of issues and solution
- Relatively simple model but no unique solution (piezo residuals +/-0.4 m average, max 0.9 m)