2nd generation

Decoding ^ Eurocode 7

Groundwater pressures in the 2nd generation Eurocodes

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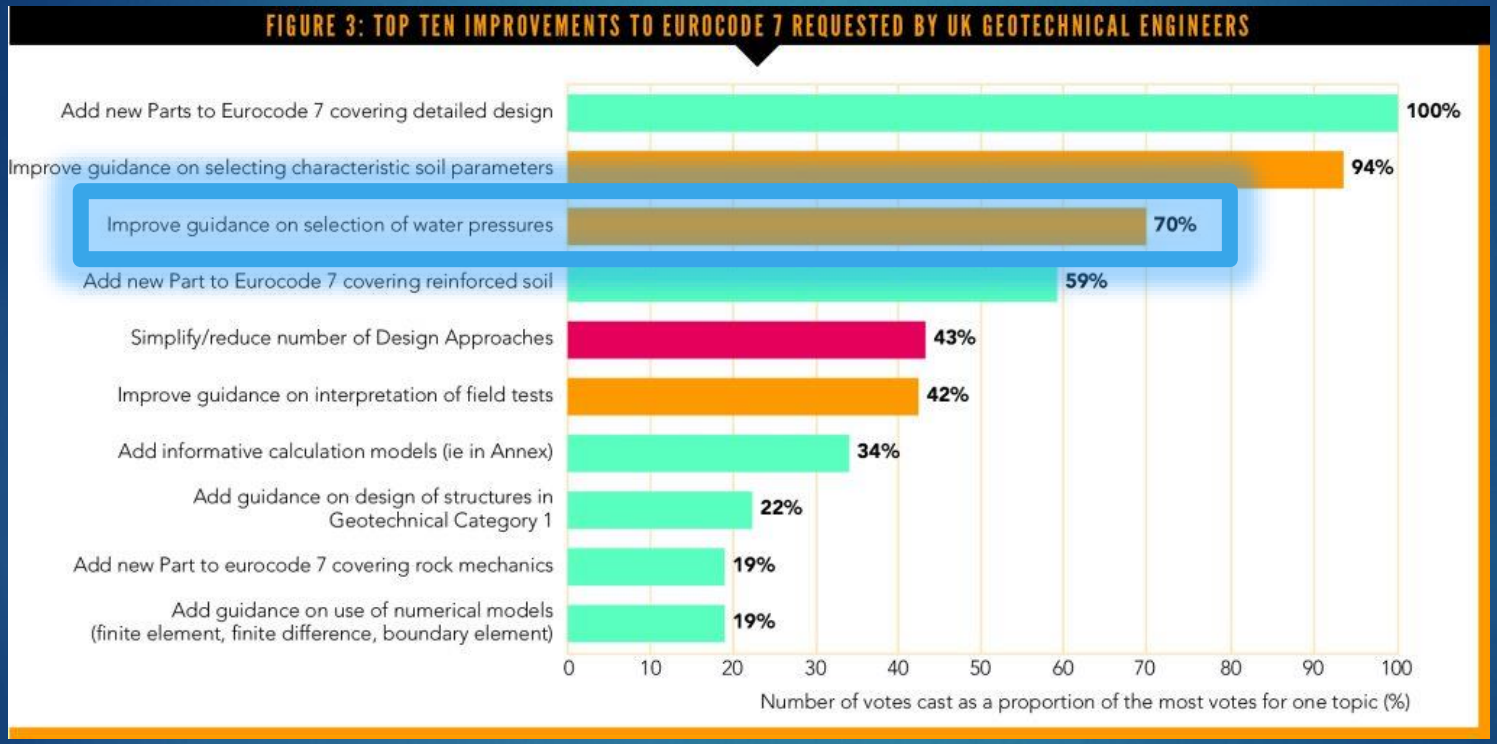
Groundwater pressures in the second-generation Eurocodes

- Water levels and pressures in the 1st-generation Eurocode 7
- Introducing the 2nd-generation Eurocodes
- Determining water levels in the 2nd-generation Eurocodes
- Summary of key points

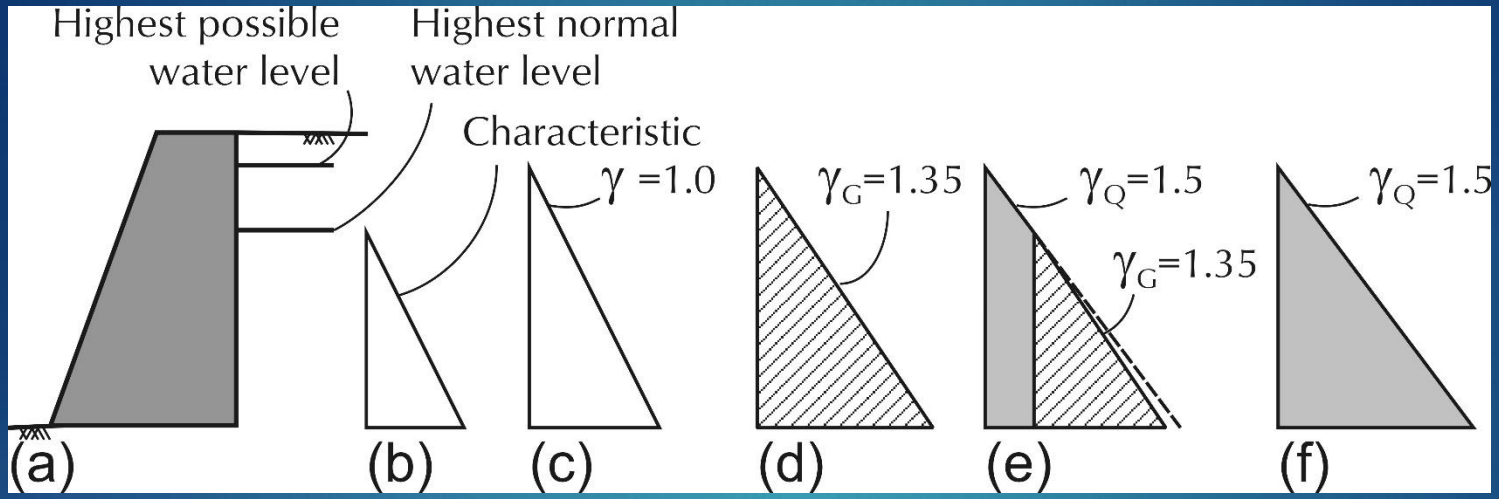
Water levels and pressures in the 1st-generation Eurocode 7

GROUNDWATER PRESSURES IN THE 2ND-GENERATION EUROCODES

Top 10 improvements requested by UK geo-engineers (Bond, 2023)



First-generation treatment of water levels and pressures (Bond and Harris, 2008)



Design value = highest water level (per EN 1997-1)

b) × no factor

c) × 1.35 (permanent)

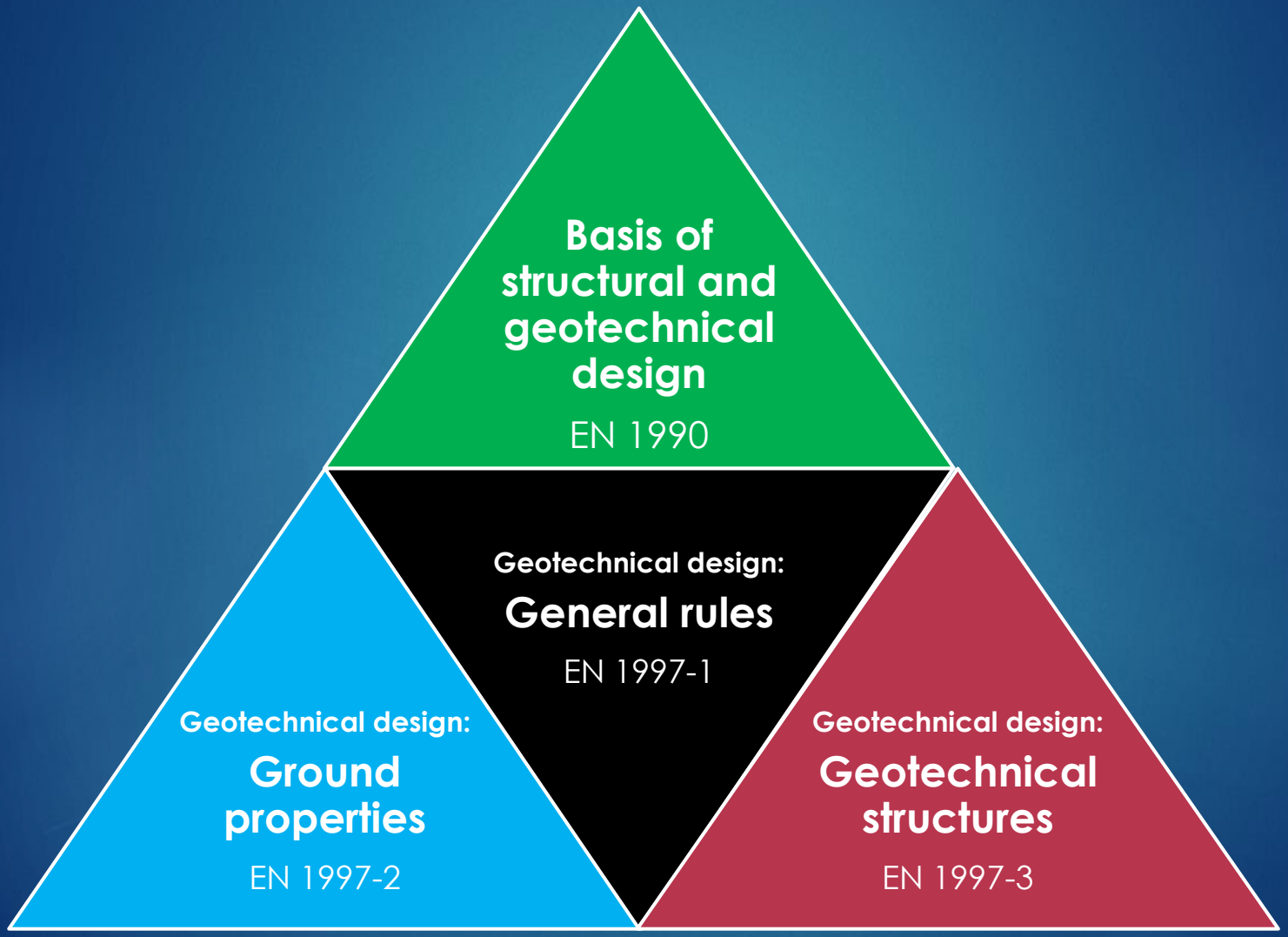
d) × 1.35 below normal level (permanent) and × 1.5 above normal (variable)

e) × 1.5 (variable)

Introducing the 2nd-generation Eurocodes

GROUNDWATER PRESSURES IN THE 2ND-GENERATION EUROCODES

2nd generation Eurocodes
Core geotechnical design standards



Second-generation Eurocode 7: Parts 1 and 2

BS EN 1997-1:2024

BSI Standards Publication

Eurocode 7 — Geotechnical design

Part 1: General rules

bsi.

BS EN 1997-2:2024

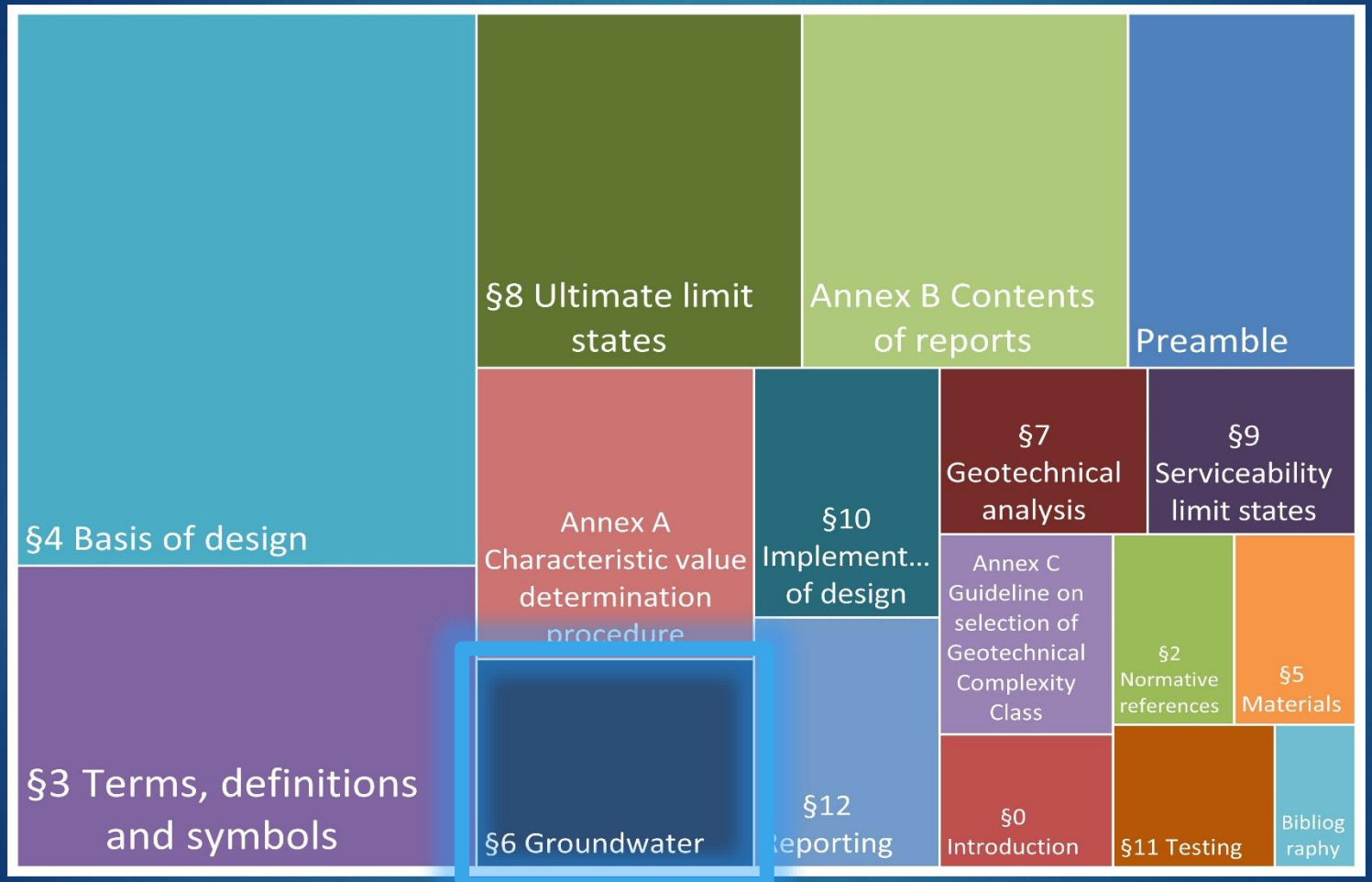
BSI Standards Publication

Eurocode 7 — Geotechnical design

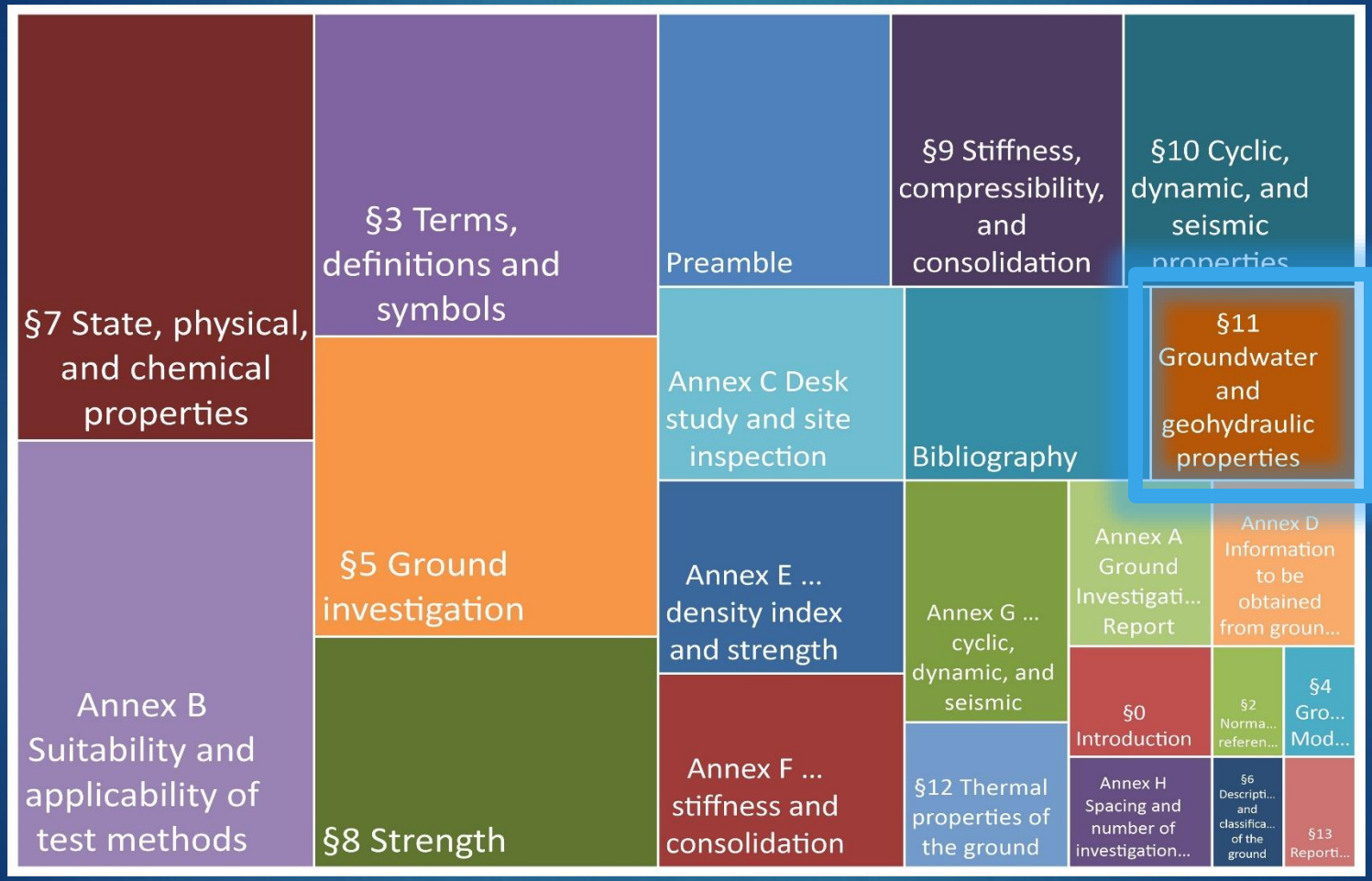
Part 2: Ground properties

bsi.

Eurocode 7 – Geotechnical design – Part 1: General rules



Eurocode 7 – Geotechnical design – Part 2: Ground properties



Determining water levels in the 2nd-generation Eurocodes

GROUNDWATER PRESSURES IN THE 2ND-GENERATION EUROCODES

Classification of water actions

"Actions that arise from water should be classified as permanent, variable, or accidental"

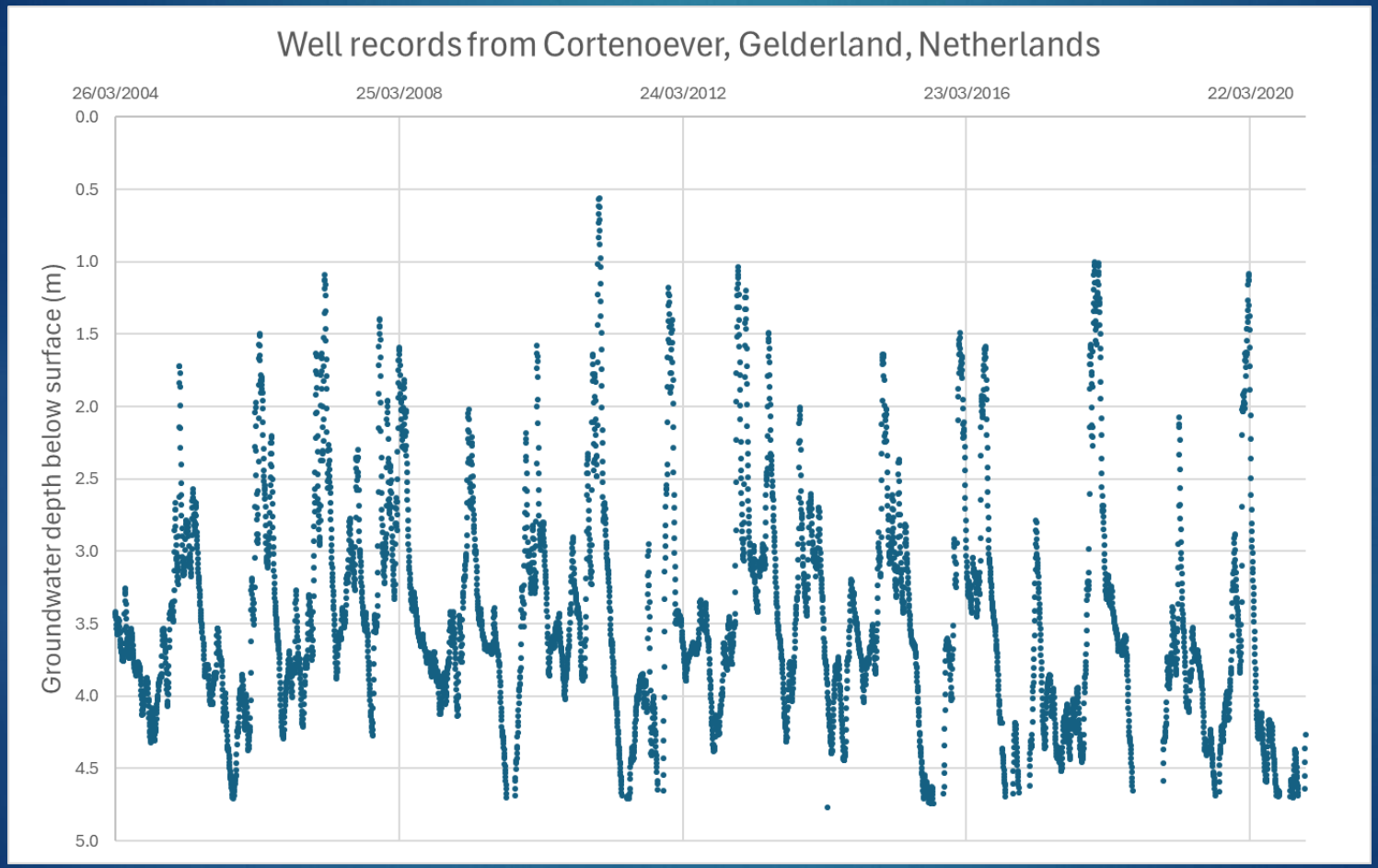
EN 1990, 6.1.3.2(1)

a permanent action (G) … is likely to act throughout the design service life and [its] **variation in magnitude is** either **small**, compared with the mean value, or … only increases or decreases, until it reaches a limit value

a variable action (Q) … is likely to occur during the design service life [but its] **variation in magnitude with time is neither negligible nor monotonic**

an accidental action (A) … [is] usually of short duration but of **significant magnitude**, that is **unlikely to occur** during the design service life

Well record from Cortenoever, Gelderland, Netherlands



Permanent water actions

When a water action is classified as permanent, its representative value $G_{w,rep}$ should be selected as one of:

- a **single characteristic value** $G_{wk,mean}$ (the **mean** value)
- the **more onerous of its characteristic values** ($G_{wk,sup}$ or $G_{wk,inf}$)
- a **nominal** value ($G_{w,nom}$)

$$\overbrace{F_{w,rep}}^{representative\ water\ action} = \overbrace{G_{w,rep}}^{permanent\ water\ action} = either \begin{cases} \overbrace{G_{wk,mean}}^{mean\ value} \\ -\ or\ - \\ \overbrace{G_{wk,sup}}^{upper\ characteristic\ value} \\ -\ or\ - \\ \underbrace{G_{wk,inf}}_{lower\ characteristic\ value} \end{cases} whichever\ is\ more\ onerous \begin{cases} -\ or\ - \\ \underbrace{G_{w,nom}}_{nominal\ value} \end{cases}$$

Variable water actions

When a water action is classified as variable, it should be represented by two components:

- a **permanent component** $G_{w,rep}$ **taken as the mean** of G_w
- a **variable component** $Q_{w,rep}$ equal to the representative value of the variation in water action

$$\overbrace{F_{\mathrm{w,rep}}}^{representative\ water\ action} = \overbrace{\underbrace{G_{\mathrm{w,rep}}}_{mean\ value}}^{permanent\ component} + \overbrace{\underbrace{Q_{\mathrm{w,rep}}}_{Q_{\mathrm{wk}}|Q_{\mathrm{w,comb}}|Q_{\mathrm{w,freq}}|Q_{\mathrm{w,qper}}}}^{variable\ component}$$

Probabilities of exceedance/time exceeded for water actions

Value of variable/ accidental water action	Symbol	Annual probability of exceedance	Return period (years)
Characteristic	Q_{wk}	2 %	50
Combination	$Q_{w,comb}$	10 %*	10
Frequent	$Q_{w,freq}$	Fraction of time exceeded = 1%	
Quasi-permanent	$Q_{w,qper}$	Fraction of time exceeded = 50%	
Accidental	$A_{w,rep}$	0.1 %	1000
*Possibility ('can be') given in EN 1990, Table A.1.7 (NDP)			

Combinations of actions for persistent and transient design situations (ULS)

General formulation:

$$\sum F_{\mathrm{d}} = \overbrace{\sum_{i \geq 1} G_{\mathrm{d,i}}}^{permanent\ actions} + \overbrace{Q_{\mathrm{d},1}}^{\substack{leading\\ variable\\ action}} + \overbrace{\sum_{j > 1} Q_{\mathrm{d,j}}}^{\substack{accompanying\\ variable\ actions}}$$

Permanent groundwater action is taken as the mean value:

$$\sum_{i \geq 1} G_{\mathrm{d,i}} = \sum_{i \geq 1} \gamma_{\mathrm{G,i}} G_{\mathrm{k,i}} = \sum_{i \geq 1} \underbrace{\gamma_{\mathrm{G,i}} G_{\mathrm{k,i}}}_{actions\ other\ than\ water} + \underbrace{\boxed{\gamma_{\mathrm{Gw}} G_{\mathrm{w,mean}}}}_{water\ action}$$

Variable groundwater actions are taken as either combination or characteristic values:

$$Q_{\mathrm{d},1} + \sum_{j > 1} Q_{\mathrm{d,j}} = \gamma_{\mathrm{Q},1} Q_{\mathrm{k},1} + \sum_{j > 1} \gamma_{\mathrm{Q,j}} \psi_{0,\mathrm{j}} Q_{\mathrm{k,j}} = \begin{cases} \overbrace{\gamma_{\mathrm{Q},1} Q_{\mathrm{k},1} + \sum_{j > 1} \gamma_{\mathrm{Q,j}} \psi_{0,\mathrm{j}} Q_{\mathrm{k,j}}}^{actions\ other\ than\ water} + \overbrace{\boxed{\gamma_{\mathrm{Qw}} Q_{\mathrm{w,comb}}}}^{\substack{combination\\ water\ action}} \\ \quad - or - \\ \underbrace{\boxed{\gamma_{\mathrm{Qw}} Q_{\mathrm{wk}}}}_{\substack{characteristic\\ water\ action}} + \underbrace{\sum_{j \geq 1} \gamma_{\mathrm{Q,j}} \psi_{0,\mathrm{j}} Q_{\mathrm{k,j}}}_{actions\ other\ than\ water} \end{cases}$$

Combinations of actions for accidental design situations (ULS)

General formulation:

$$\sum F_{\mathrm{d}} = \overbrace{\sum_{i \geq 1} G_{\mathrm{d,i}}}^{permanent\ actions} + \overbrace{\boxed{A_{\mathrm{d}}}}^{\substack{accidental \\ action}} + \overbrace{Q_{\mathrm{d,1}}}^{\substack{leading \\ variable \\ action}} + \overbrace{\sum_{j > 1} Q_{\mathrm{d,j}}}^{\substack{accompanying \\ variable\ actions}}$$

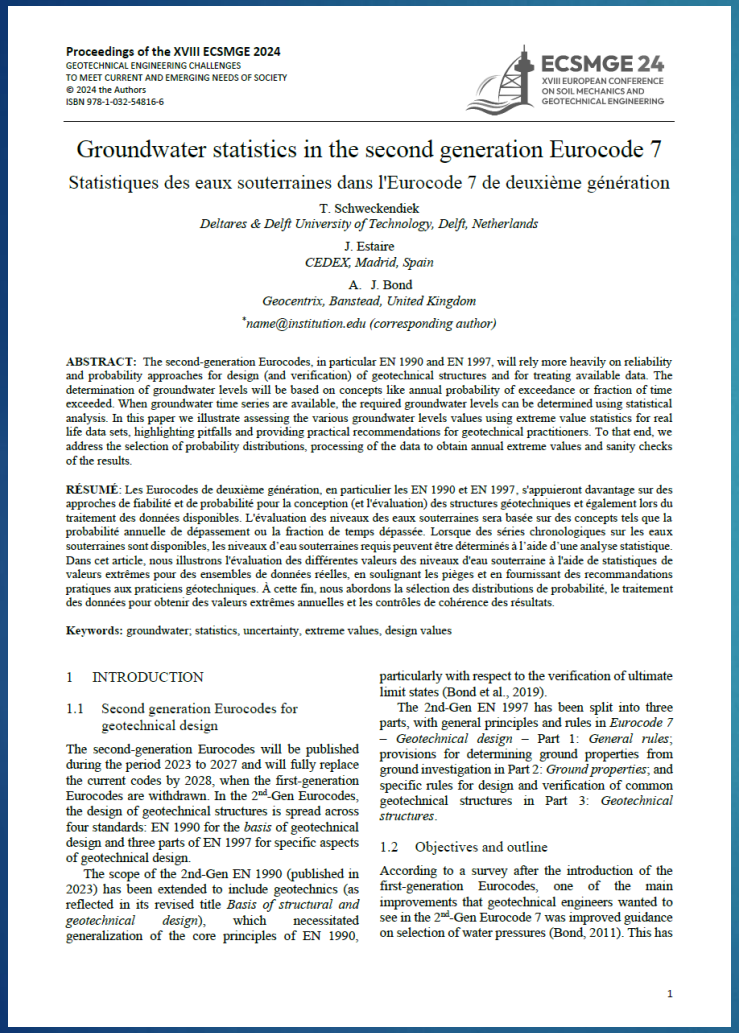
When the **accidental action** is from groundwater:

$$A_{\mathrm{d}} + Q_{\mathrm{d,1}} + \sum_{j > 1} Q_{\mathrm{d}} = \overbrace{\boxed{A_{\mathrm{wd}}}}^{\substack{accidental \\ water\ action}} + \overbrace{\gamma_{\mathrm{Q,1}}\psi_{1,1}Q_{\mathrm{k,1}} + \sum_{j > 1} \gamma_{\mathrm{Q,j}}\psi_{2,\mathrm{j}}Q_{\mathrm{k,j}}}^{actions\ other\ than\ water}$$

When the **variable actions** include groundwater:

$$A_{\mathrm{d}} + Q_{\mathrm{d,1}} + \sum_{j > 1} Q_{\mathrm{d,j}} = A_{\mathrm{d}} + \begin{cases} \overbrace{\gamma_{\mathrm{Q,1}}\psi_{1,1}Q_{\mathrm{k,1}} + \sum_{j > 1} \gamma_{\mathrm{Q,j}}\psi_{2,\mathrm{j}}Q_{\mathrm{k,j}}}^{actions\ other\ than\ water} + \overbrace{\boxed{\gamma_{\mathrm{Qw}}Q_{\mathrm{w,qper}}}}^{\substack{quasi-permanent \\ water\ action}} \\ \quad - or - \\ \overbrace{\boxed{\gamma_{\mathrm{Qw}}Q_{\mathrm{w,freq}}}}^{\substack{frequent \\ water\ action}} + \overbrace{\sum_{j > 1} \gamma_{\mathrm{Q,j}}\psi_{2,\mathrm{j}}Q_{\mathrm{k,j}}}^{actions\ other\ than\ water} \end{cases}$$

Groundwater statistics in the second-generation Eurocode 7



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Groundwater statistics in the second generation Eurocode 7

Statistiques des eaux souterraines dans l'Eurocode 7 de deuxième génération

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ABSTRACT: The second-generation Eurocodes, in particular EN 1990 and EN 1997, will rely more heavily on reliability and probability approaches for design (and verification) of geotechnical structures and for treating available data. The determination of groundwater levels will be based on concepts like annual probability of exceedance or fraction of time exceeded. When groundwater time series are available, the required groundwater levels can be determined using statistical analysis. In this paper we illustrate assessing the various groundwater levels values using extreme value statistics for real life data sets, highlighting pitfalls and providing practical recommendations for geotechnical practitioners. To that end, we address the selection of probability distributions, processing of the data to obtain annual extreme values and sanity checks of the results.

RÉSUMÉ: Les Eurocodes de deuxième génération, en particulier les EN 1990 et EN 1997, s'appuieront davantage sur des approches de fiabilité et de probabilité pour la conception (et l'évaluation) des structures géotechniques et également lors du traitement des données disponibles. L'évaluation des niveaux des eaux souterraines sera basée sur des concepts tels que la probabilité annuelle de dépassement ou la fraction de temps dépassée. Lorsque des séries chronologiques sur les eaux souterraines sont disponibles, les niveaux d'eau souterraines requis peuvent être déterminés à l'aide d'une analyse statistique. Dans cet article, nous illustrons l'évaluation des différentes valeurs des niveaux d'eau souterraine à l'aide de statistiques de valeurs extrêmes pour des ensembles de données réelles, en soulignant les pièges et en fournissant des recommandations pratiques aux praticiens géotechniques. À cette fin, nous abordons la sélection des distributions de probabilité, le traitement des données pour obtenir des valeurs extrêmes annuelles et les contrôles de cohérence des résultats.

Keywords: groundwater; statistics, uncertainty, extreme values, design values

1 INTRODUCTION

1.1 Second generation Eurocodes for geotechnical design

The second-generation Eurocodes will be published during the period 2023 to 2027 and will fully replace the current codes by 2028, when the first-generation Eurocodes are withdrawn. In the 2nd-Gen Eurocodes, the design of geotechnical structures is spread across four standards: EN 1990 for the *basis* of geotechnical design and three parts of EN 1997 for specific aspects of geotechnical design.

The scope of the 2nd-Gen EN 1990 (published in 2023) has been extended to include geotechnics (as reflected in its revised title *Basis of structural and geotechnical design*), which necessitated generalization of the core principles of EN 1990, particularly with respect to the verification of ultimate limit states (Bond et al., 2019).

The 2nd-Gen EN 1997 has been split into three parts, with general principles and rules in *Eurocode 7 – Geotechnical design* – Part 1: *General rules*; provisions for determining ground properties from ground investigation in Part 2: *Ground properties*; and specific rules for design and verification of common geotechnical structures in Part 3: *Geotechnical structures*.

1.2 Objectives and outline

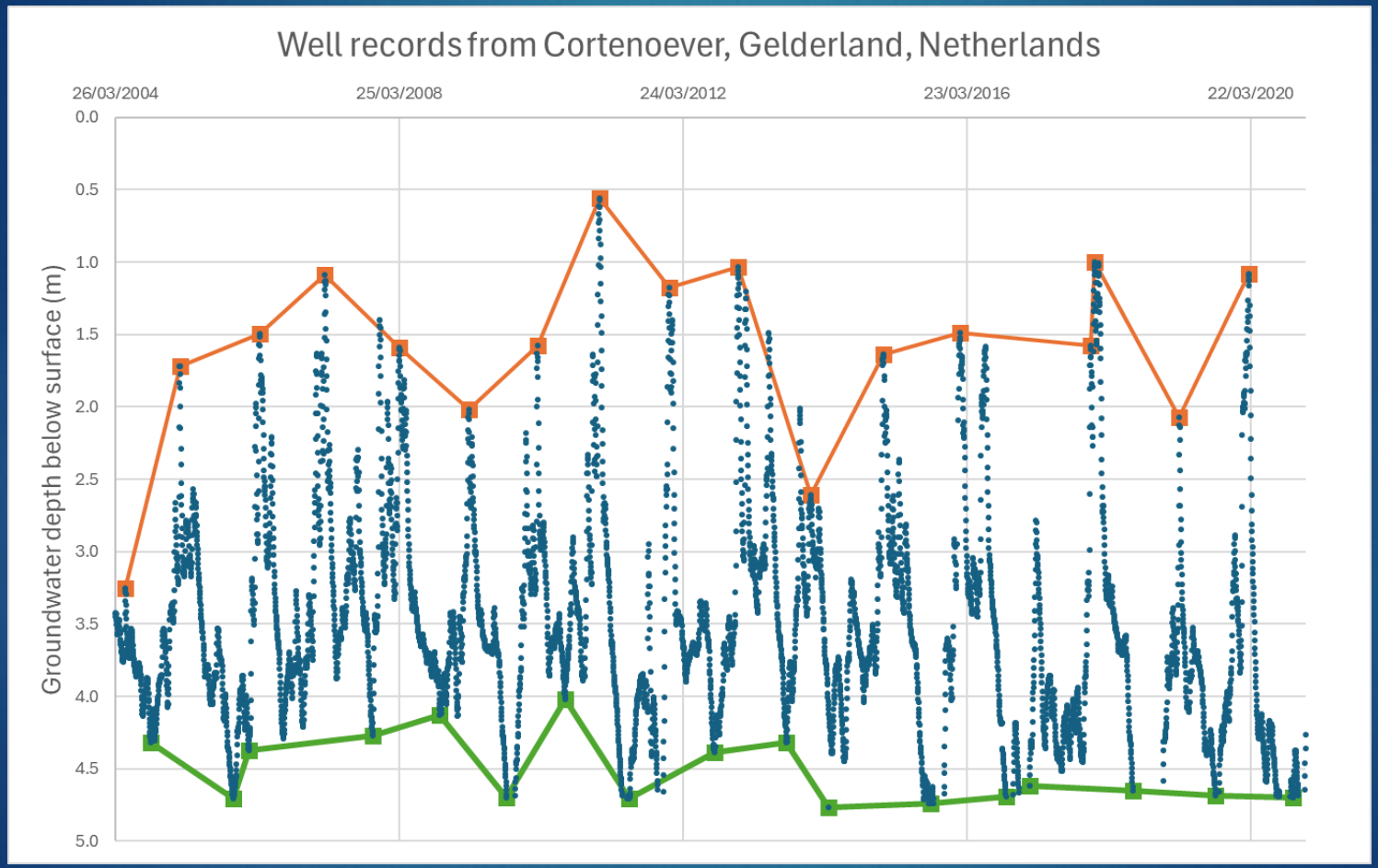
According to a survey after the introduction of the first-generation Eurocodes, one of the main improvements that geotechnical engineers wanted to see in the 2nd-Gen Eurocode 7 was improved guidance on selection of water pressures (Bond, 2011). This has

1

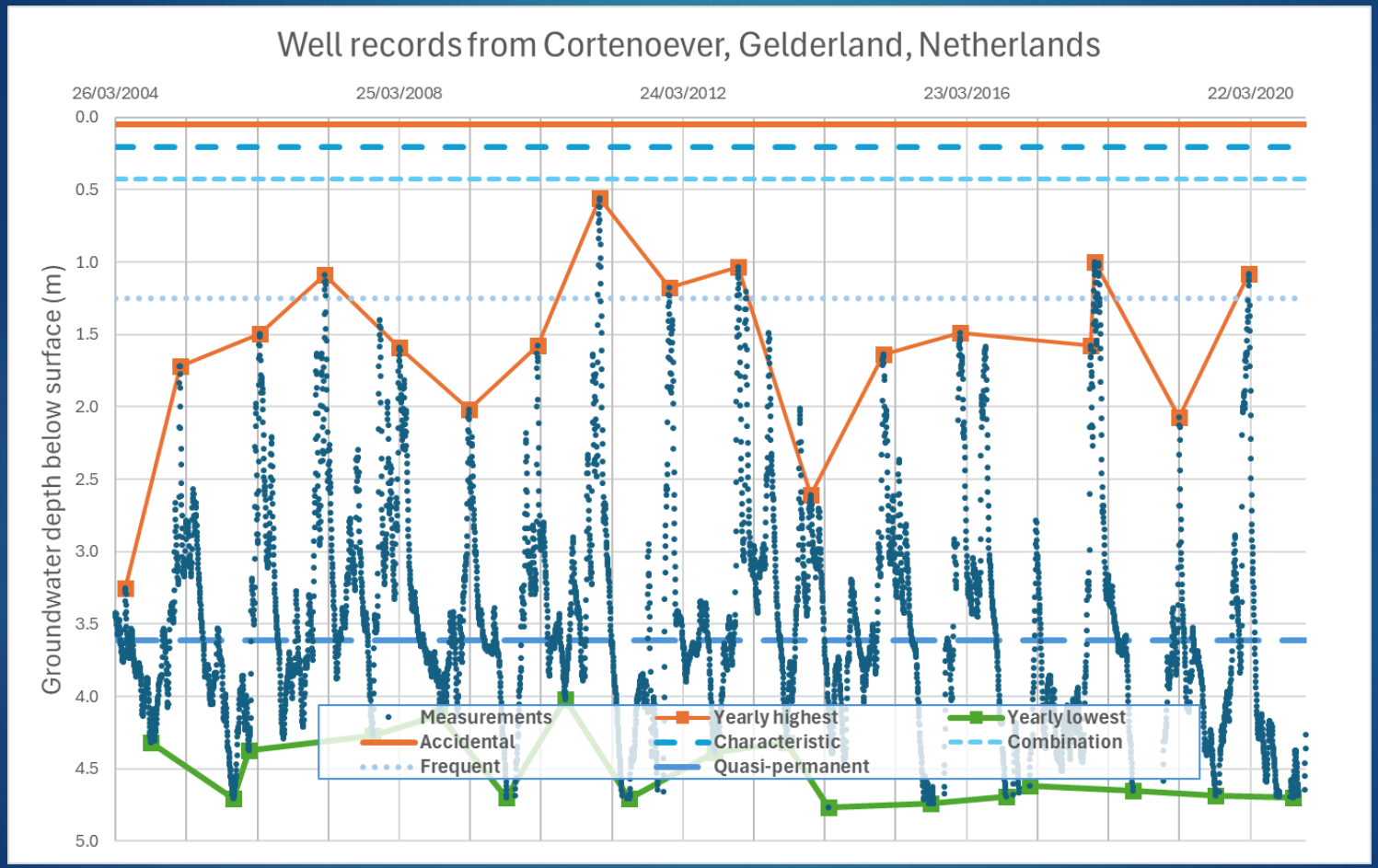
Paper

- by Timo Schweckendiek, Jose Estaire, and Andrew Bond
- to be published in 18th European Conference on Soil Mechanics and Geotechnical Engineering, Lisbon
- addresses the **selection of probability distributions**, **processing of the data** to obtain annual extreme values, and **sanity checks** of the results

Annual maxima and minima groundwater levels



Example of variable water levels



Partial factors for fundamental design situations (general application)

Action or effect				Partial factors γ_F and γ_E for Verification Cases 1-4				
Type	Group	Symbol	Resulting effect	Struct-ural*	Static equilibrium and uplift**		Geotechnical design	
				VC1	VC2(a)	VC2(b)	VC3	VC4
Permanent action (G_k)	All	γ_G	unfavourable/ destabilizing	**1.35 k_F**	**1.35 k_F**	1.0	1.0	G_k is not factored
	Water	$\gamma_{G,w}$		**1.2 k_F**	**1.2 k_F**			
	All	$\gamma_{G,stb}$	stabilizing	not used	**1.15**		not used	
	Water	$\gamma_{Gw,stb}$			1.0			
	(All)	$\gamma_{G,fav}$	favourable	1.0	1.0		1.0	
Prestressing (P_k)		γ_P	See other relevant Eurocodes					
Variable action (Q_k)	All	γ_Q	unfavourable	**1.5 k**	**1.5 k**		**1.3**	***
	Water	γ_{Qw}		**1.35 k_F**	**1.35 k_F**		**1.15**	1.0
	(All)	$\gamma_{Q,fav}$	favourable	0				
Effects-of-actions (E)		γ_E	unfavourable	γ_E is not applied				**1.35 k_F**
		$\gamma_{E,fav}$	favourable					1.0

*Also used for geotechnical design; **Less favourable outcome of (a) and (b) applies
***$\gamma_{Q,red} = \gamma_{Q,1}/\gamma_{G,1}$, where $\gamma_{G,1}$ = value of $\gamma_{G,1}$ from VC1 and $\gamma_{Q,1}$ = value of $\gamma_{Q,1}$ from VC1
Values taken from EN 1990, Annex A.1

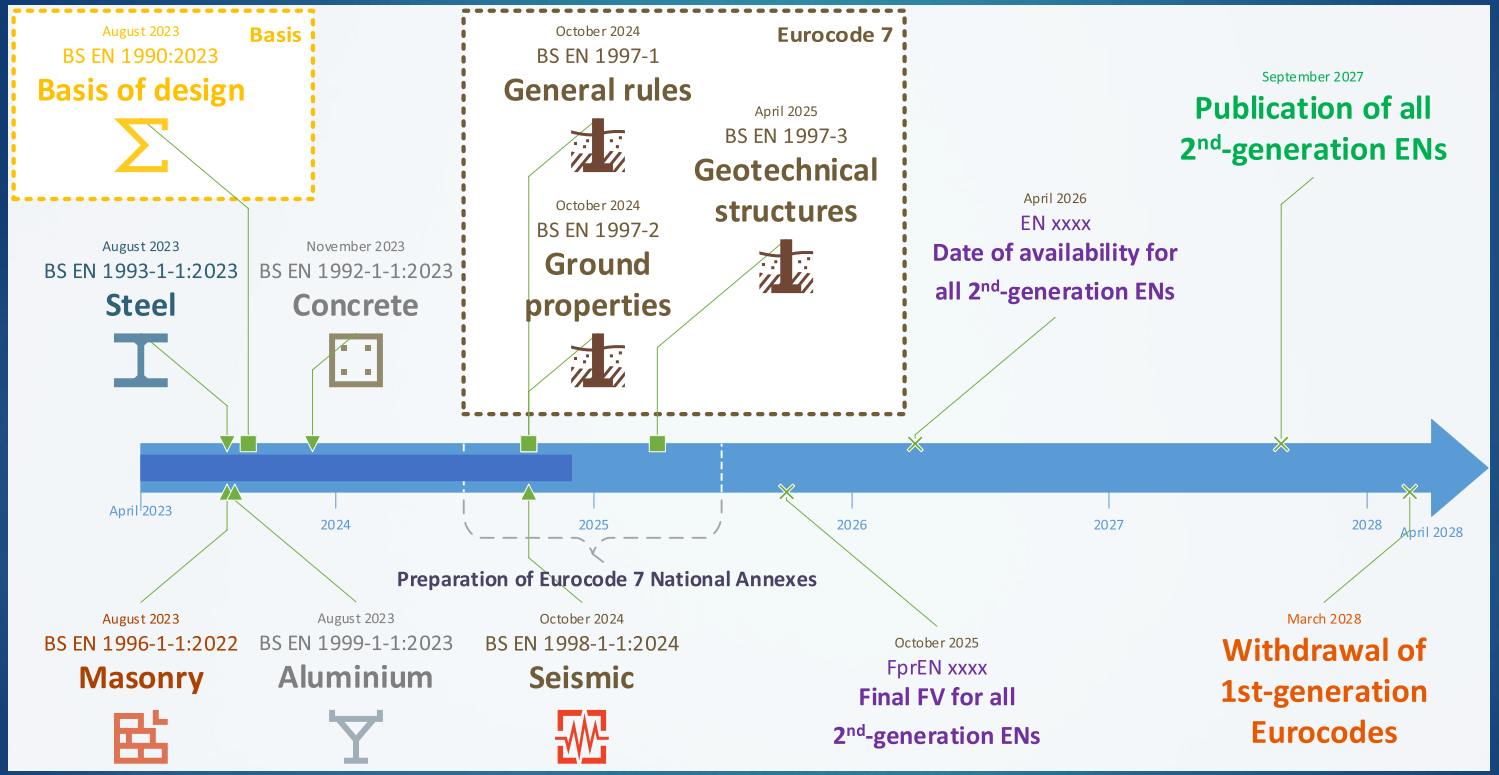
Summary of key points

GROUNDWATER PRESSURES IN THE 2ND-GENERATION EUROCODES

Summary of key points

- EN 1990 now provides **detailed specification of water actions**
- Water actions can be permanent, variable, or accidental
- **Permanent** water actions are represented by:
  - a **single characteristic value based on the mean**
  - **upper and lower values** based on 5 % fractiles
- **Variable** water actions are represented by:
  - the **mean** water action (permanent) **plus**
  - the **variation** in water action (characteristic, combination, frequent, or quasi-permanent value)
- **Accidental** water actions are represented by:
  - value with **1000 year return period**

Timetable for the introduction of the second-generation Eurocodes



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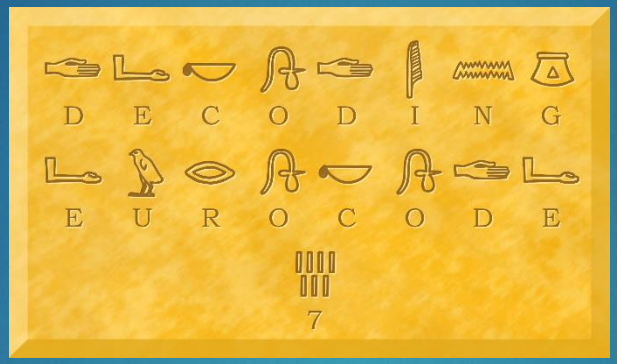

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- Decoding Eurocode 7 –
  - Basis of geotechnical design
  - Ground properties (and ground investigation)
  - Shallow foundations
  - Deep foundations
- Decoding Eurocode 3 – Steel foundations

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Ground properties

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