Development of a Well Impairment Model for Predicting Geothermal Clogging

DIMOPREC project

09/05/2022

TU Delft

Deltares

VEEGEO Geothermal Energy

Rijksdienst voor Ondernemend Nederland

Program

- 10:00 Coffee
- 10:05 Introduction by Karl-Heinz Wolf
- 10:10 Roll call – introduction Bart van den Berg
- 10:20 Ahmed Hussain: Progress and status deliverables
- 10:45 Bernhard Meulenbroek: Explanation of the model architecture
- 11:10 Ayla Reerink / Han Claringbould: The Skid
- 11:30 Wouter van der Star: First skid application and link to model development
- 11:50 Discussion and final conclusions
- 12:10 Lunch at LABS

2 - Aim and activities of the work packages (WP) (1/4)

+ 2 ½ months (started March 16th 2020)

WP of Fase [3]	Korte beschrijving	Categorie: IO of EO[4]	Uitvoerders (met namen)[5]	Resultaat	Geplande begin- en einddatum[6]
WP 1 Screening and evaluation of selected Dutch geothermal doublets					
1a	Evaluation and screening	IO, EO	TU Delft, VeeGeo, Deltares	Upgrading the mineral database with available kinetic and reaction parameters for candidate Dutch geothermal fields.	1-20 – 5-20
1b	Statistically quantification	IO	TU Delft	*Development of relevant statistically procedure for problem simplification based on task1.a*	3-20 – 10-20
WP 2 Full-field modelling, workflow and quantifying					
2a	Model based quantitative criteria	IO	TU Delft, Deltares	*Generic analytical model and analysis based on quantitative criteria to evaluate the importance of kinetics of geo-chemical reactions, An innovative approach to simplify the numerical simulation*	5-20 – 10-20
2b	Full-field predictive model & workflow	IO	TU Delft, Deltares	*Numerical model development and work flow providing governing mechanism in field scale, Presenting quantitative key parameters and operational strategies being relative to avoid or treat clogging*	6-20 – 9-21
WP 3 3 Demonstration and implementation for Dutch geothermal reservoirs					
3a	Case studies for test and validation	IO, EO	TU Delft, VeeGeo, Deltares	Presenting the optimized operational parameters for relevant minerals to minimize the risk of precipitation, Detailed validated geo-chemical mechanisms of the selected pilot areas	9-20 – 10-21
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3c	Development of a corrosion skid specific for field testing	IO, EO	TU Delft, VeeGeo, Deltares	testing of scale formation and influence on scaling rates	1-21 – 10-21
WP 4 Project management, coordination and dissemination					
4a	Project coordination	IO, EO	TU Delft	The Project Agreement agreed and signed by all project members (TU Delft)	1-20 – 12-21
4b	Project management and control	IO, EO	TU Delft	For all WP's, the dissemination and reports on final results (TU Delft, all), The periodical overview of the project (TU Delft, all partners, every 12 months)	1-20 – 12-21
4c	Dissemination	IO	TU Delft, VeeGeo, Deltares	Presentation of the project and its findings during international conferences and in scientific peer-reviewed publications – conference proceedings, bibliographic data of scientific papers, workshops, Reporting every 12 months	1-20 – 12-21

2 - Aim and activities of the work packages (WP) Status September 2020 (2/4)

Status September 2020

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Sent extended abstract to EAGE conference

TU Delft

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		See submissions on RVO site			
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✓ Abstract and presentation at EGU 2021 conference

TU Delft

2 - Aim and activities of the work packages (WP) Status May 2022 (4/4)

+ 2 ½ months (started March 16th 2020)

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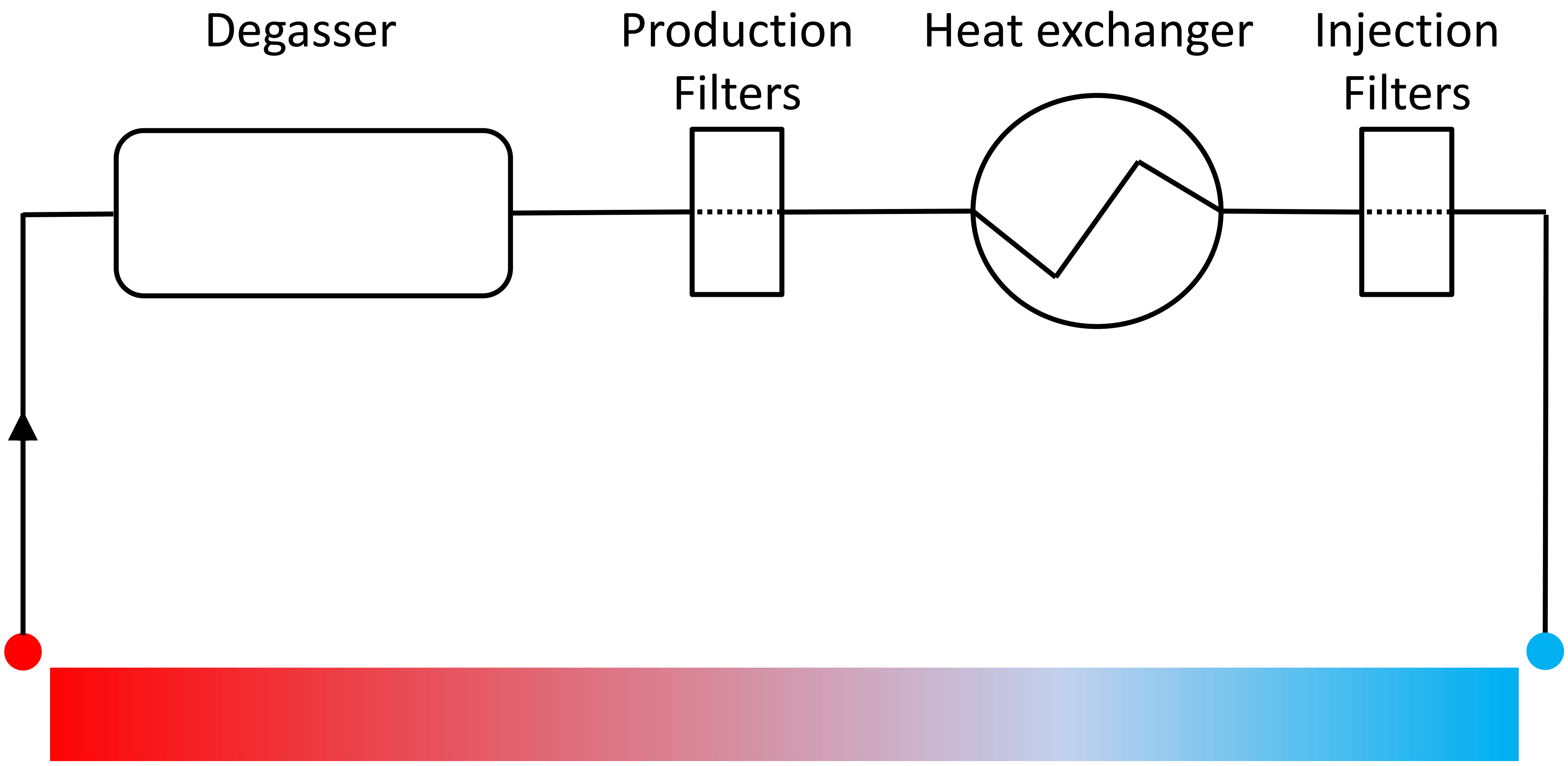
Spin-off: SKID to be used for DAP well in 2023

Spin-off: NL project on Lithium 'mining' from geothermal waste water

TU Delft

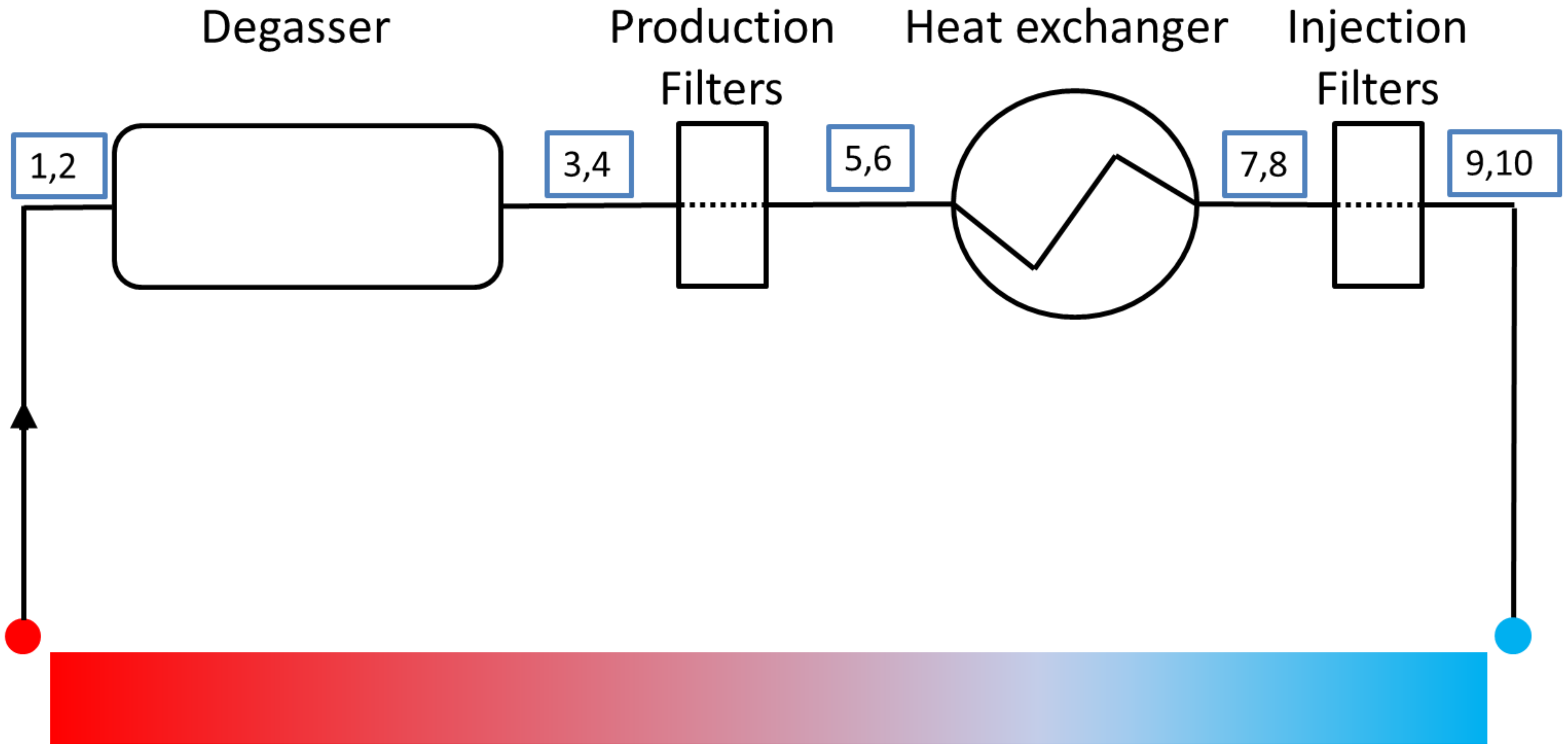
Ahmed

Schematic of system



Water composition from geothermal facility

field case A, composition used for numerical study



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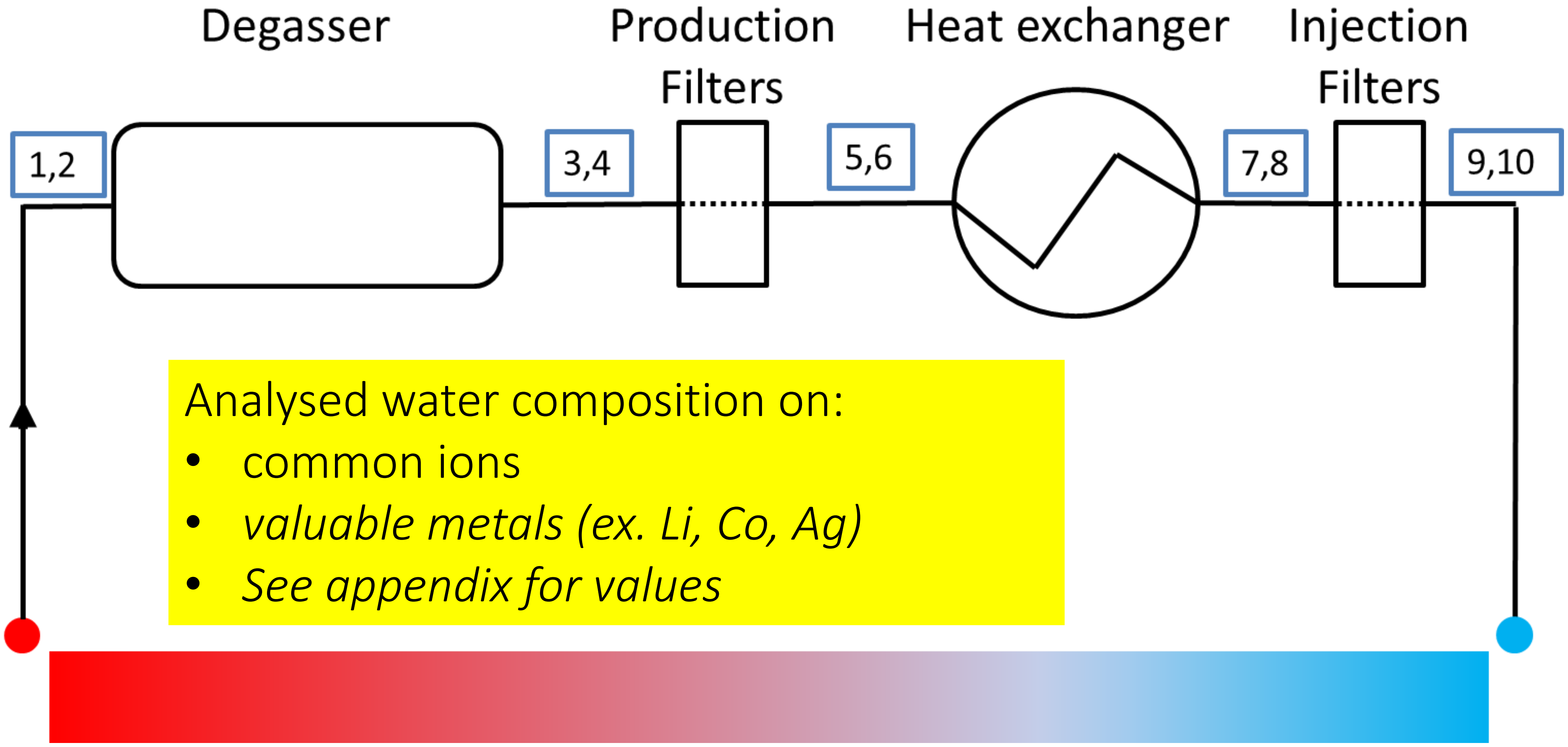
Water composition from geothermal facility

field case A, composition used for numerical study



Analysed water composition on:

- common ions
- *valuable metals (ex. Li, Co, Ag)*
- *See appendix for values*

Field case modelling – subsurface

Modelling scale forming near injection well, where impact of scaling in reservoir is most significant on well injectivity

Approach

1. Cross check PHREEQC library with mineral composition of filter residue and well scaling (WP 1a)
2. Insert water composition from geothermal facility into PHREEQC, ideally from injection well
3. Check in PHREEQC which minerals precipitate based on 'saturation indices', example:

---Saturation indices---

Phase	SI**	log IAP	log K(308 K, 5 atm)	
Anhydrite	-0.87	-5.26	-4.39	CaSO4
Aragonite	-5.09	-13.49	-8.40	CaCO3
Barite	0.58	-9.25	-9.83	BaSO4
Calcite	[illegible]	-3.24	1.62	Ca1Cl03
Celestite	-1.14	-6.86	-5.72	SrSO4

4. Using analytic work, determine whether mineral kinetics are 'slow' (can be ignored), 'intermediate' (must be numerically calculated), 'fast' (can be assumed to occur instantaneous) → WP 2a.
5. Numerical simulation of the intermediate reactions, using a coupled PHREEQC and COMSOL approach. WP 2b/3a

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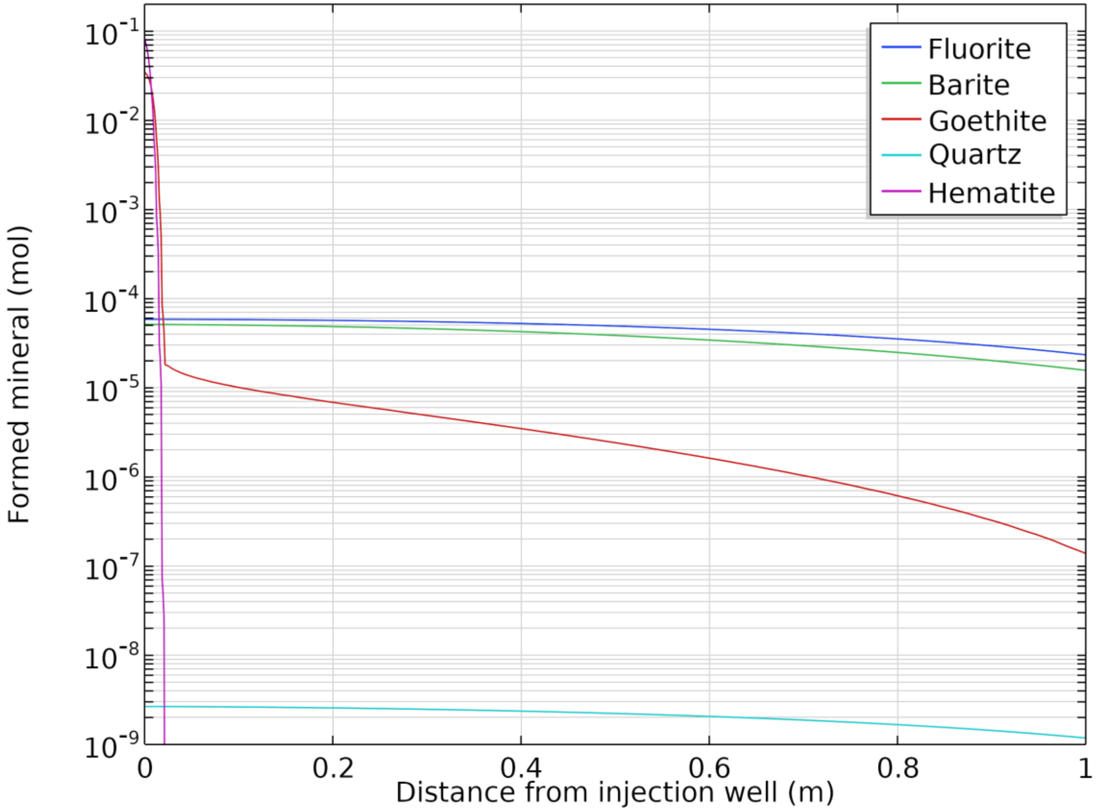
Field case modelling – subsurface

Modelling scale forming near injection well, where impact of scaling in reservoir is most significant on well injectivity

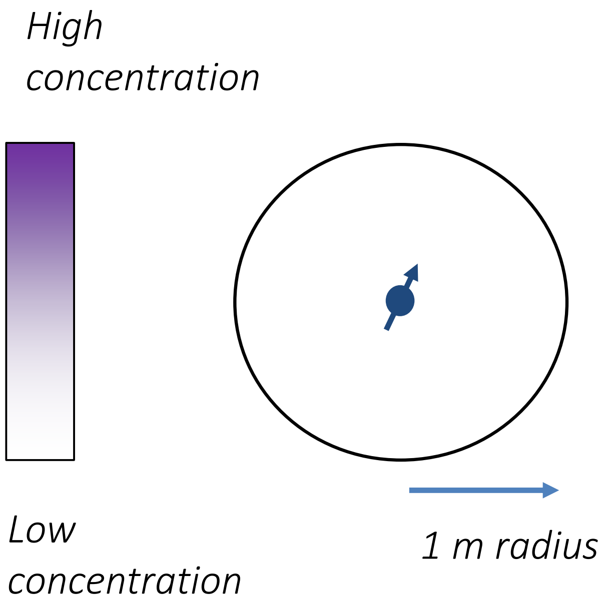


Fluorite:	*CaF_2*
Barite:	*$BaSO_4$*
Goethite:	*FeO(OH)*
Quartz:	*SiO_2*
Hematite:	*Fe_2O_3*
Injection rate:	*300 [m^3/hr]*
Reservoir thickness:	*30 [m]*
Porosity:	*0.15 [-]*
Well radius:	*0.05 [m]*
Injection time:	*400 [s]*
Injection temperature:	*35 [degC]*

TU Delft

Field case modelling - subsurface

Modelling scale forming near injection well, where impact of scaling in reservoir is most significant on well injectivity

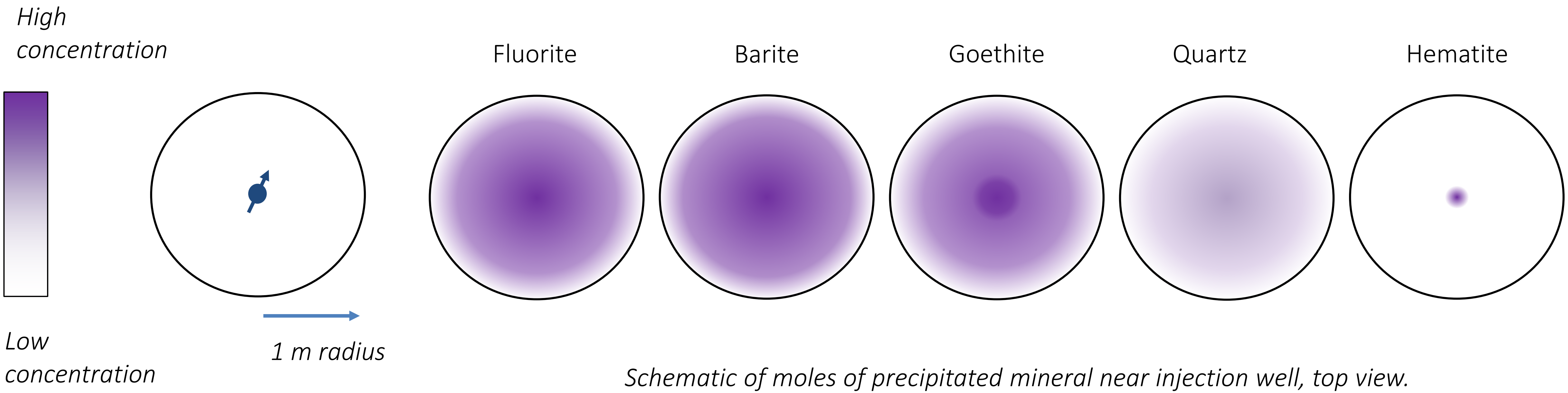


Schematic of moles of precipitated mineral near injection well, top view.

Color is not to scale.

Field case modelling - subsurface

Modelling scale forming near injection well, where impact of scaling in reservoir is most significant on well injectivity



Schematic of moles of precipitated mineral near injection well, top view.

Color indicates concentration, purple higher, white low. Color is not to scale.

Field case modelling

Modeling surface facilities mineral scale forming
Stirred tank approach

Approach

1. Cross check PHREEQC library with mineral composition of filter residue and well scaling (WP 1a)
2. Insert water composition from geothermal facility into PHREEQC, ideally from production well or PVT
3. Check in PHREEQC which minerals precipitate based on 'saturation indices', example:

------------------------------Saturation indices------------

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4. Simulate precipitation of minerals within facility using 'stirred tank' (WP 2b/WP 3a)

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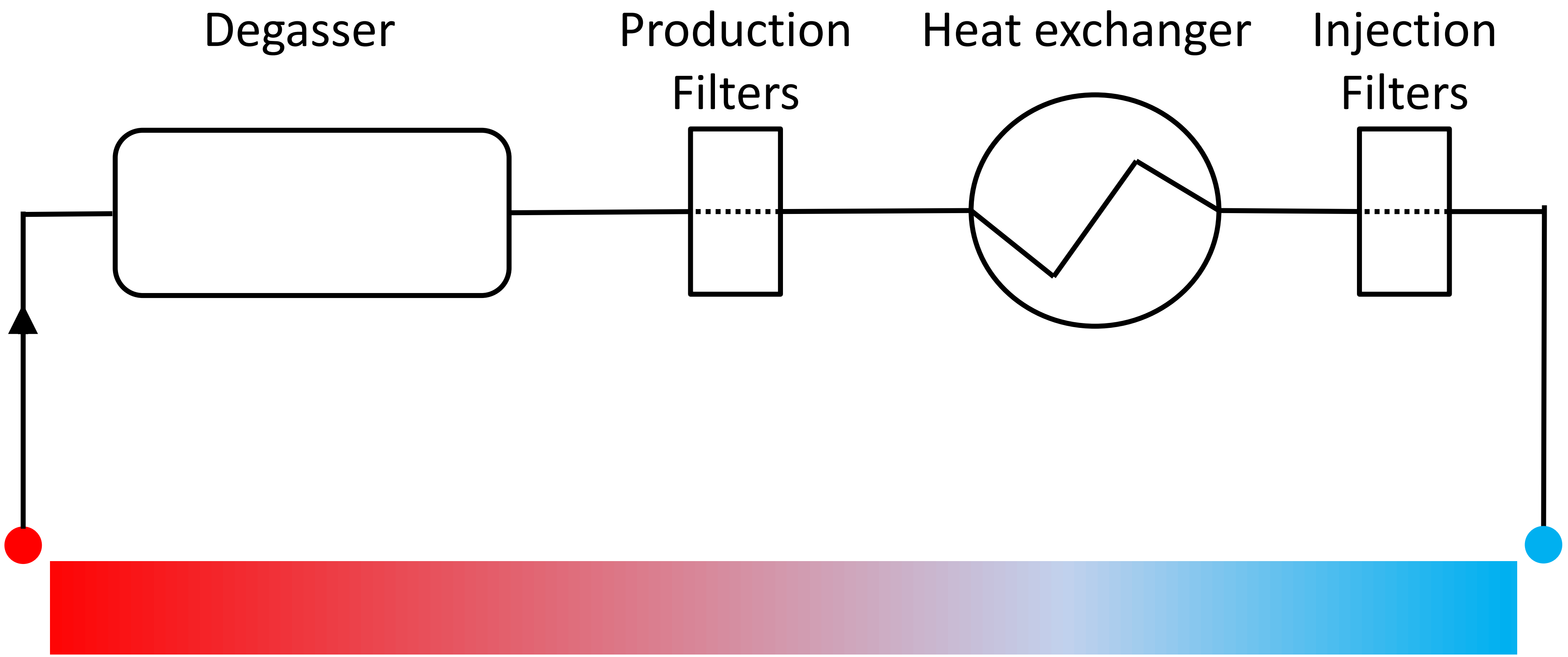
Field case modelling

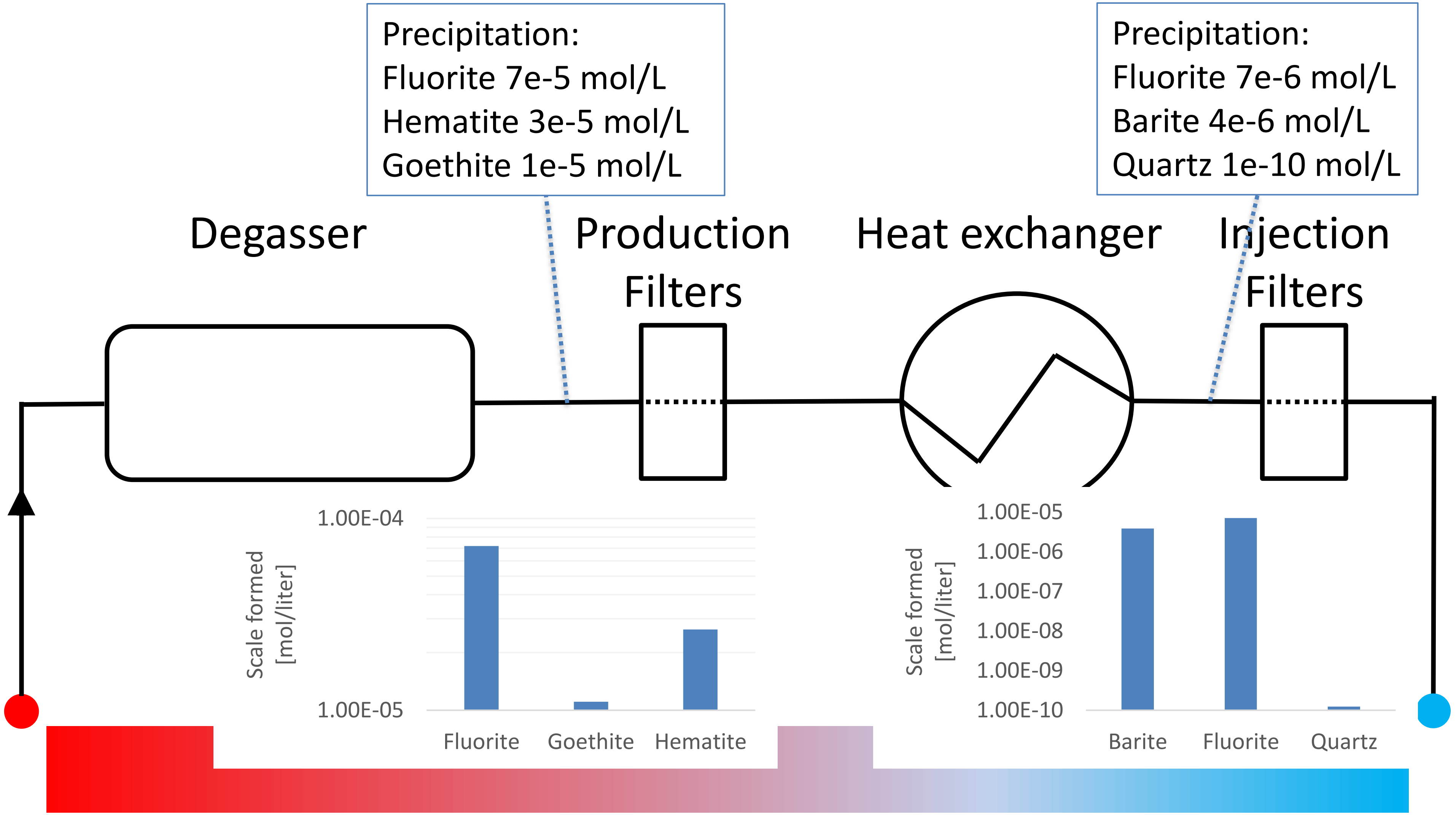
Modeling surface facilities mineral scale forming
Stirred tank approach



Field case modelling

Modeling surface facilities mineral scale forming

Stirred tank approach



TU Delft

Bernard Meulenbroek

- Combination of analytical work (fast) with numerical work (more detailed, but slower) → detailed conclusions quickly visualised for subsurface reactions.

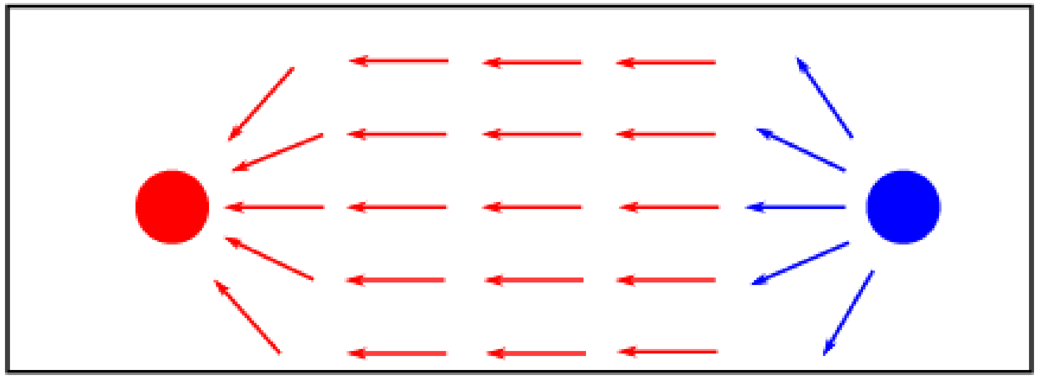
TUDelft

DIMOPREC: mathematical modelling

- Modelling transport
- Modelling chemistry
- Timescales: fast, intermediate and slow
- Numerical approach
- Numerical and analytical results
- Conclusions and outlook

Modelling transport

Top view of the subsurface



Heat: convection, (conduction)
Dissolved species: convection, (diffusion), reaction

Modelling chemistry (1)

$$A+B \leftrightarrow AB$$

$\rightarrow$: forward reaction, precipitation
$\leftarrow$: backward reaction, dissolution

Forward rate = backward rate $\Rightarrow$ equilibrium

Modelling chemistry (2)

- Rates depend on conditions like concentrations, temperature
- Conditions are changing due to injection cold water
- Reservoir not in equilibrium anymore

Challenges

- Many species and reactions
- Reaction timescales differ many orders of magnitude

Timescales: fast, intermediate and slow; D2A

Analytical work (1)

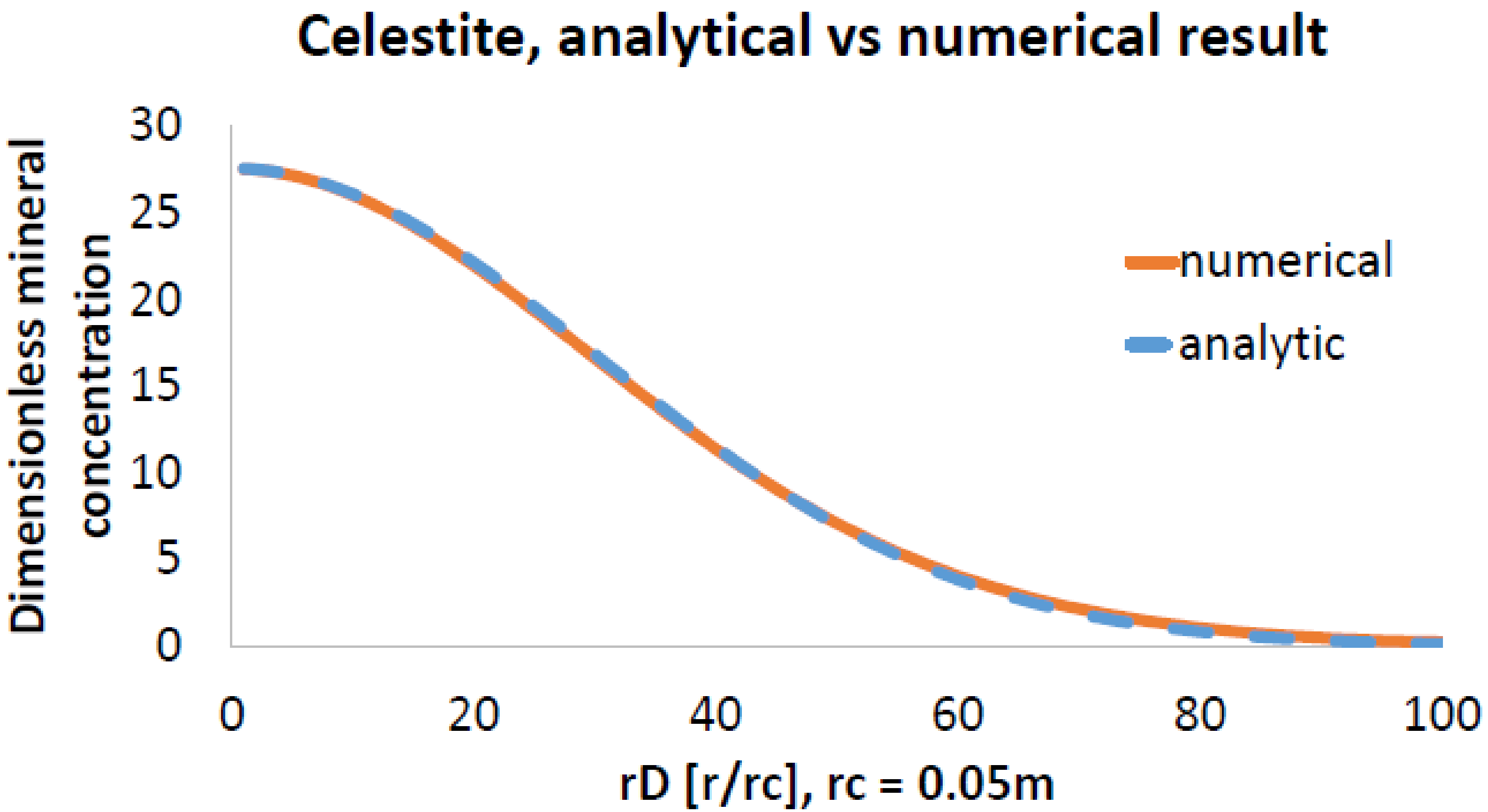
- Fast: "instanteneous" equilibrium
- Slow: influence reaction negligible
- Intermediate: include reaction kinetically

Analytical work (2)

Explicit solution model equations in specific cases

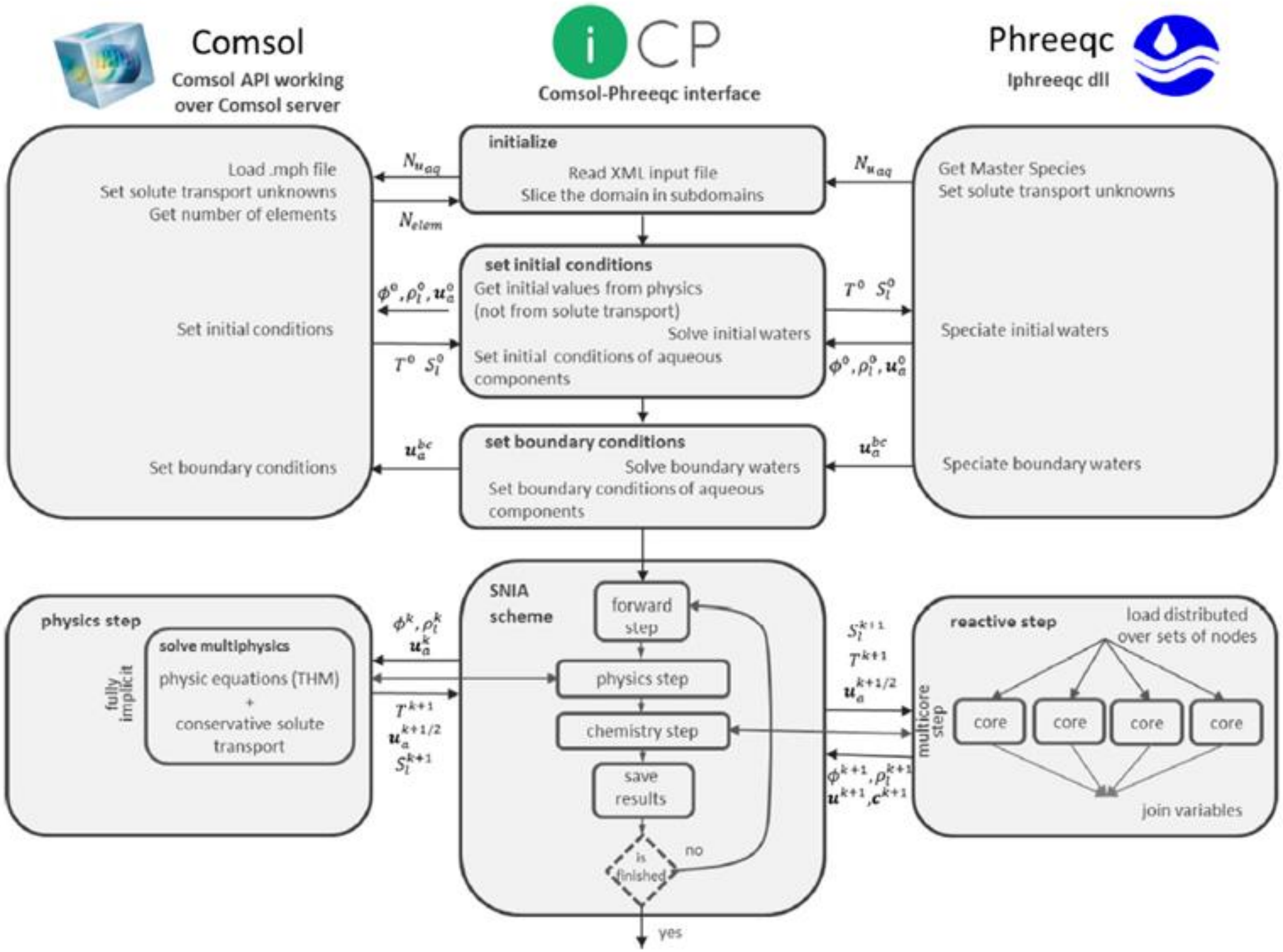
TUDelft

An example of the results



TUDelft

Numerical approach D2B



Conclusions and outlook

- Analytical results allow classification and simplification (speed up)
- Numerical approach validated
- Now: extension to field case
- To do: control scaling (vary temperature, pH)

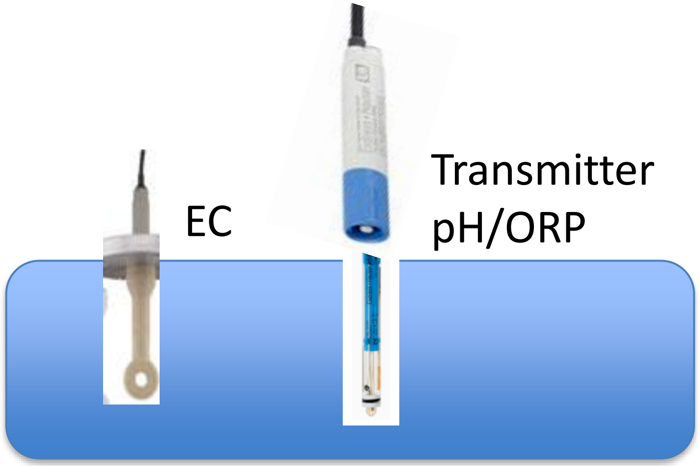
Veegeo: content

- Overview and current status
- Equipment overview

Overview and current status

- Skid testing - ✓
- Sensor equipment ordered - ✓
- Skid remodeling meeting – week 19-20
- Planned commissioning – week 22-24?

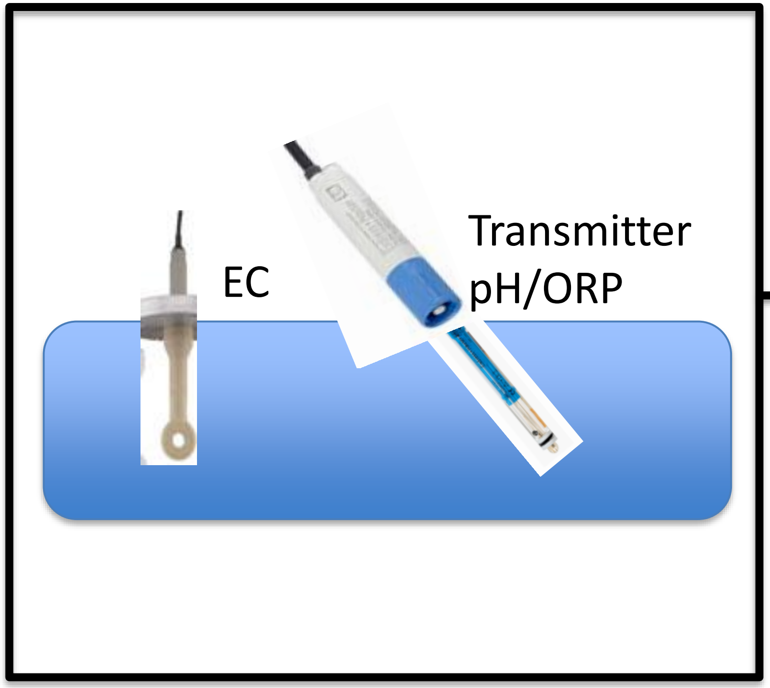
Equipment overview

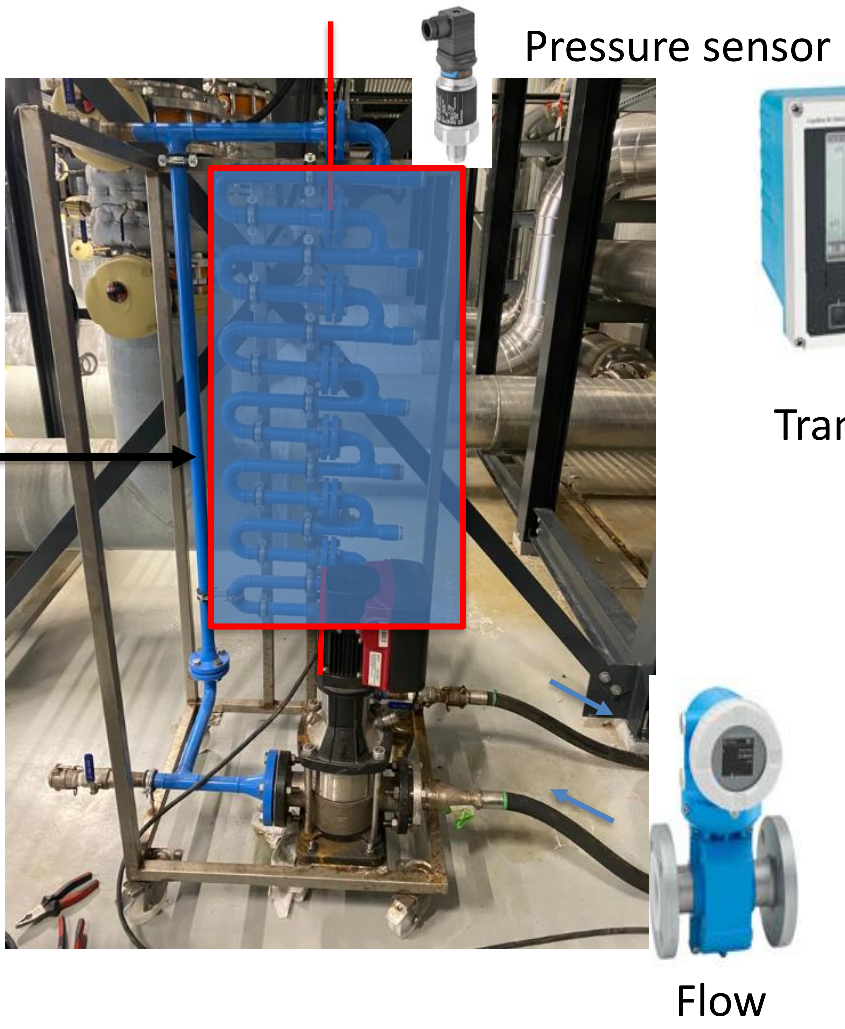


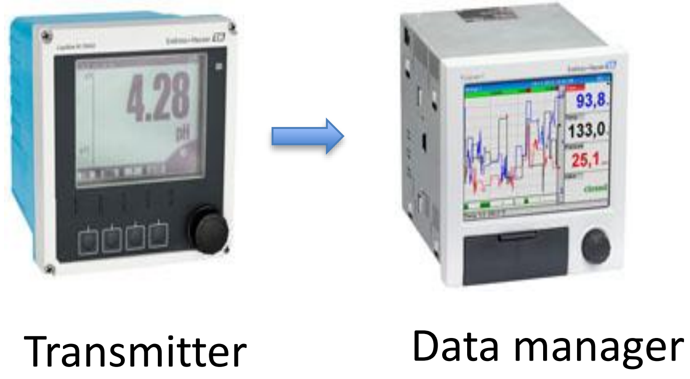
Transmitter

Data manager

Equipment overview







TO DO:
Change out vertical setup with horizontal set up

TUDelft

Wouter van der Star/Deltares

First employment of the skid

Dynamic model in soil

Skid for continuous monitoring + offline sampletaking

→ Validation+testing

Goals:

- →validate proper functioning
- →discover functioning characteristics (like calibration frequency etc)
- →evaluate variations
- →test offline measurement options
- →2 locations

Questions / discussions

Appendix

- Water composition over length of facilities.

Measured ion concentrations at field case A

		Ion concentration [ppb] measured in process water, at multiple locations in facility, see schematic for locations									
Element	**Average**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Ag	0.5	0.8	0.5	0.4	0.5	0.5	0.4	0.4	0.3	0.4	0.4
Al	12	14	16	10	10	13	11	13	11	11	14
As	156	150	159	153	165	162	159	160	149	150	155
Ba	7,411	7,402	7,266	7,319	7,262	7,181	7,335	7,081	7,276	8,724	7,266
Br	536,200	507,200	507,200	567,000	567,000	549,800	549,800	507,200	507,200	549,800	549,800
Ca	6,103,940	6,252,600	6,252,600	5,665,500	5,665,500	6,174,500	6,174,500	6,252,600	6,252,600	6,174,500	6,174,500
Cl	85,048,600	84,437,000	84,437,000	85,615,000	85,615,000	85,377,000	85,377,000	84,437,000	84,437,000	85,377,000	85,377,000
Cd	-	-	-	-	-	-	-	-	-	-	-
Co	10	11	11	9	10	9	9	10	10	10	10
Cr	66	72	67	55	60	49	50	104	73	68	58
Cu	109	40	45	59	77	333	301	55	83	46	48
F	180,780	199,800	199,800	166,300	166,300	169,000	169,000	199,800	199,800	169,000	169,000
Fe57	66,647	62,952	65,097	62,574	68,008	61,229	63,410	69,565	72,960	69,411	71,268
K	276,657	278,629	276,580	275,105	280,959	275,568	276,301	278,647	276,822	271,773	276,188
Li	4,947	4,594	5,274	5,446	5,380	4,940	4,792	4,722	4,626	4,688	5,010
Mg	1,679,900	1,690,900	1,690,900	1,695,700	1,695,700	1,661,000	1,661,000	1,690,900	1,690,900	1,661,000	1,661,000
Mn	1,238	1,161	1,143	1,251	1,267	1,243	1,253	1,300	1,268	1,239	1,252
Mo	2	2	2	2	2	2	2	2	2	2	2
Na	42,967,400	42,347,000	42,347,000	43,473,000	43,473,000	43,335,000	43,335,000	42,347,000	42,347,000	43,335,000	43,335,000
Ni	181	150	156	183	202	186	180	187	204	187	178
Pb	11	43	14	6	6	10	10	11	6	6	3
S	-	-	-	-	-	-	-	-	-	-	-
Se	3	8	9	1	-	-	-	7	-	8	8
Si	21,697	21,445	21,172	22,817	22,612	21,049	21,790	21,804	22,137	20,693	21,446
SO4	2,112,280	2,066,000	2,066,000	2,155,800	2,155,800	2,136,800	2,136,800	2,066,000	2,066,000	2,136,800	2,136,800
Ti	236	257	195	431	212	216	204	195	248	207	199
V	-	2	2	-	-	-	-	-	-	1	-
Zn	284	752	672	139	120	308	325	128	121	112	165