TERRATEC

Well Stimulation Technologies

TERRATEC
WELL STIMULATION TECHNOLOGIES

Terratec solutions are focused on producing and injecting wells.



- Terratec has both chemical and physical methods to optimize oil production, waterflooding and improve oil recovery.
- It provides increasing well oil production rate and injectivity in given pattern.
- Terratec technologies have been successfully applied in many fields in Russia, Canada, Europe, Central Asia with very good results and HSE record.
- Our research team continues to innovate and improve current technologies through laboratory research and field pilots.

HQ, office, laboratory and field departments are in Moscow.

SUPER FLUID WATER – WATER CONFORMANCE CONTROL (CHEMICAL FLOODING)

PROBLEM: OIL FIELD DEVELOPMENT WITH WATERFLOODING

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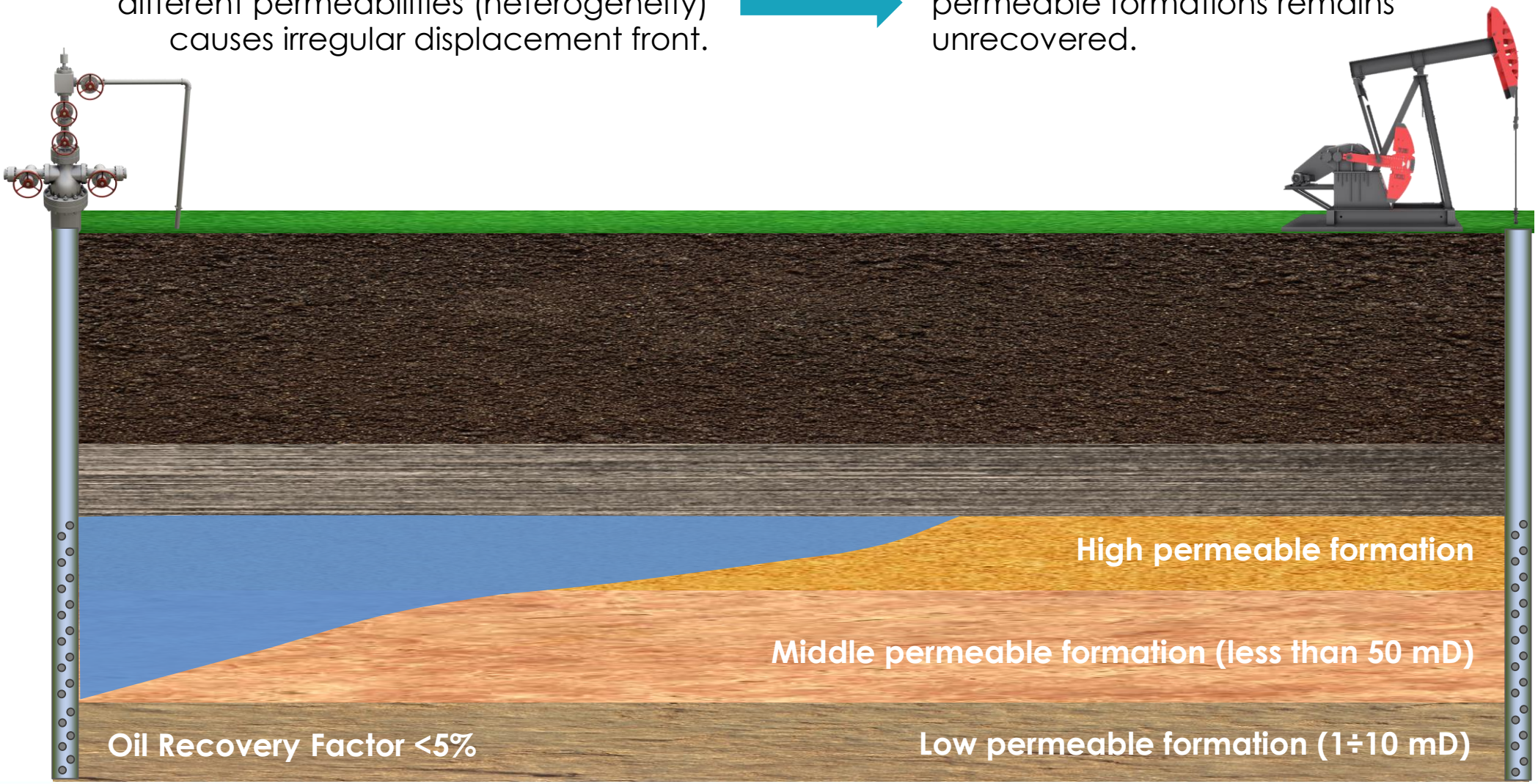
Waterflooding of reservoirs with different permeabilities (heterogeneity) causes irregular displacement front.

Large part of reserves in low-permeable formations remains unrecovered.



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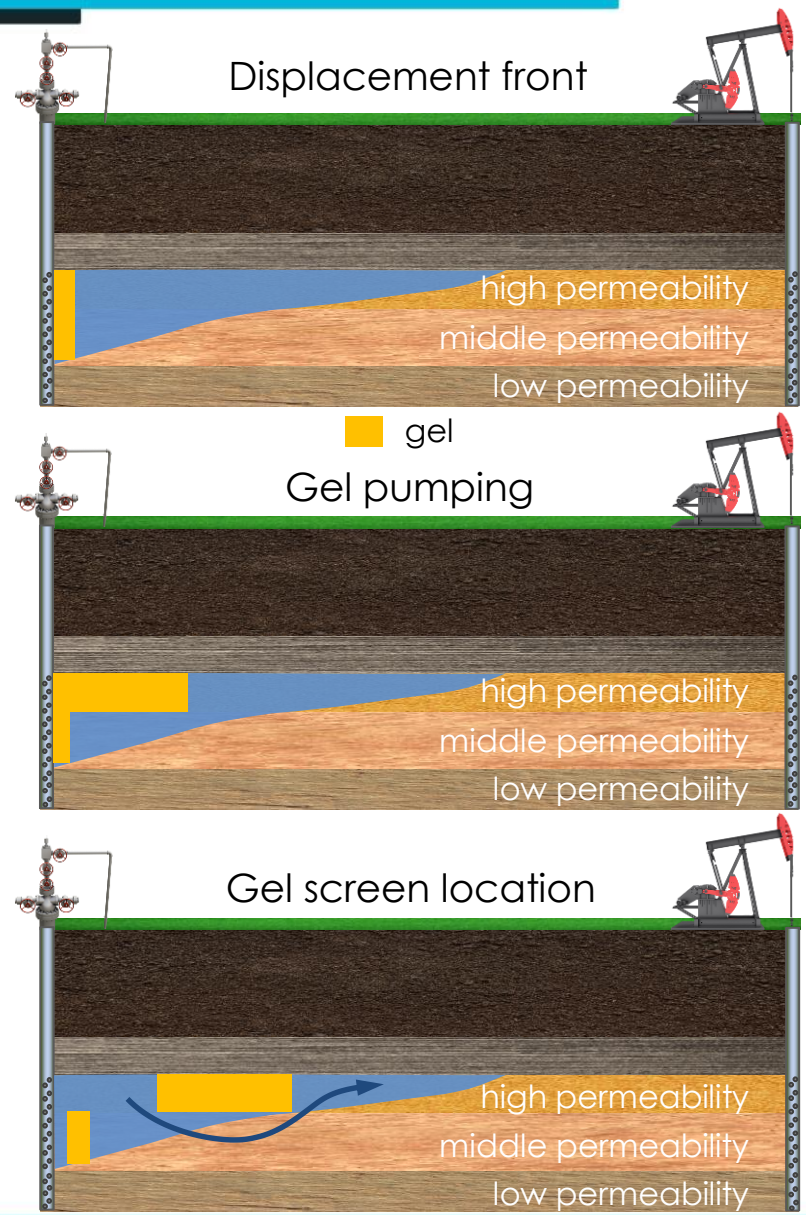
Standard solution for conformance control

Gel injection

Blocking highly permeable intervals for drainage of low permeable intervals.

Main concerns:

- Decreases the injectivity index of injector, which negatively affects the recovery of reservoir pressure.
- Limited opportunity to redistribute the displacing agent over the interlayers.
- Impossibility to attract in the process of oil displacement the most low-permeable layers.
- Works only in the near-wellbore zone.



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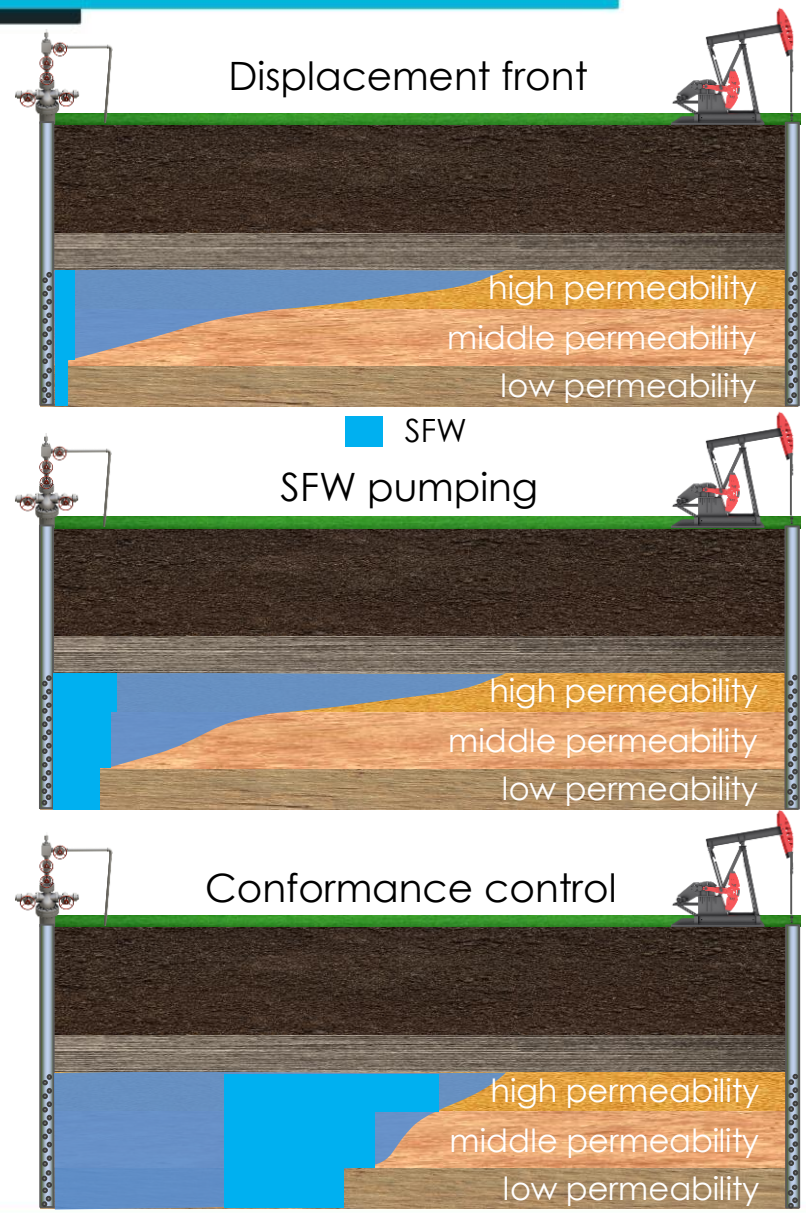
Terratec's solution for conformance control

TerraFlow Surer Fluid Water (SFW)

Increase of water permeability of low-permeable interlayers with practically unchanged permeability of high-permeable intervals.

Main advantages:

- Previously undrained reserves in low-permeability interlayers are involved in the development.
- Reserves drained in highly permeable interlayers continue to participate in the development.
- Penetrates a long distance in the reservoir.



HYDROPHOBIZATION OF SILICA SURFACE

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Mechanism of Surfactant action.

Physical adsorption

Silica hydrophobization

The permeability of the reservoir layer after HYDROPHOBIZATION is 3 and more times higher than the hydrophilic collector.

Mechanism of SFW action

Chemisorption

Consumption of solution during chemisorption is **2 ÷ 3 orders** of magnitude less

Physical adsorption	Chemical adsorption
1) Adsorption heat ~ 10 ÷30 kJ/mol	1) ~ 100 ÷ 300 kJ/mol
2) Adsorption rate W ~ a – number of strokes	2) W = a·exp(-E/RT), where E>80÷120 kJ/mol
3) Temperature dependence of speed W ~ a ~ √T	3) W ~ exp(-E/RT) – speed increases dramatically with temperature
4) Adsorption is non-specific and its adsorbability range is preserved on any adsorbent.	4) Adsorption is specific. A substance may react with one adsorbent, but not with another.

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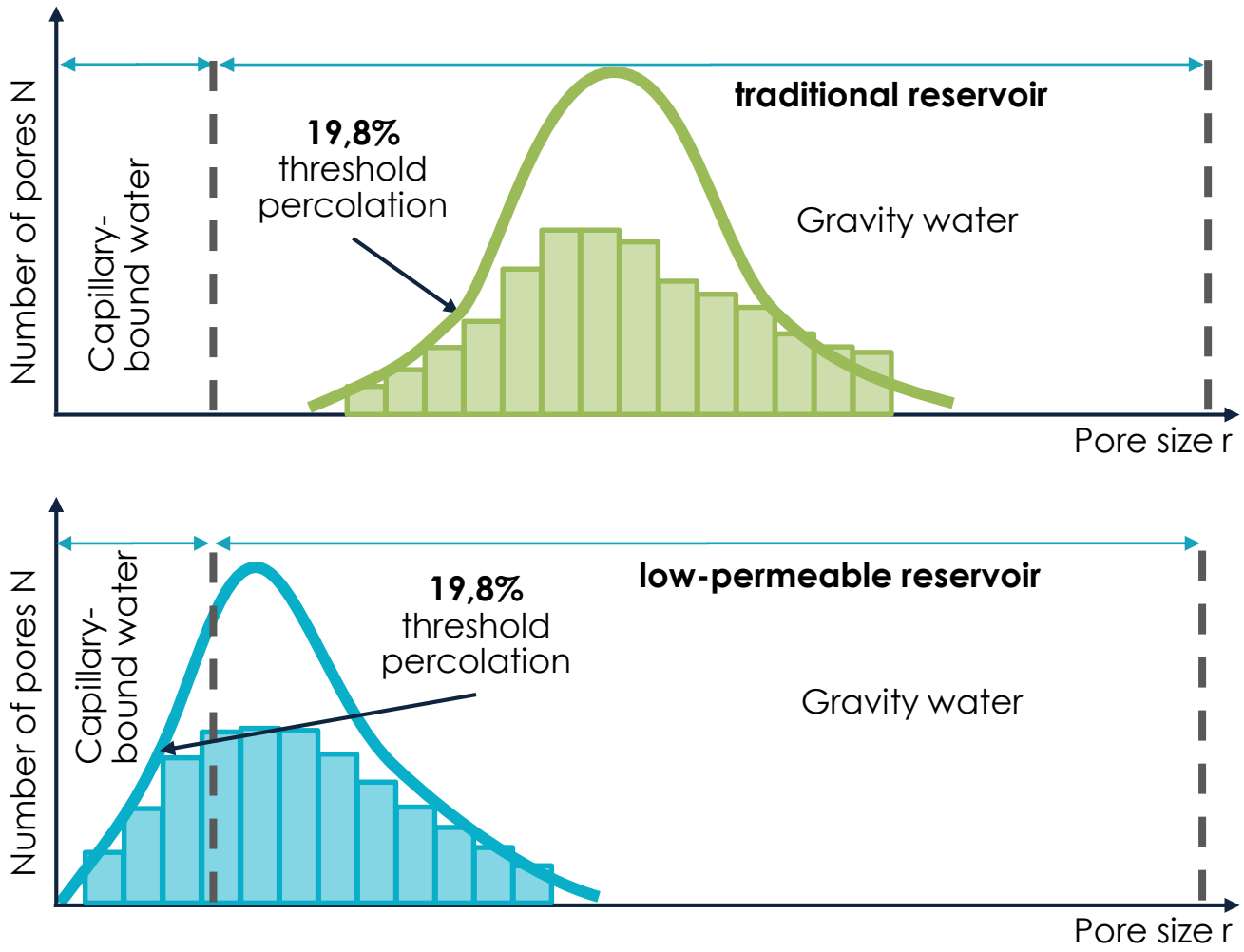
Fluid flow conditions in terrigenous reservoir



The percolation threshold is the minimum value at which the flow of liquid through the porous medium begins.

Since the percolation threshold in the low-permeable reservoir covers the region of capillary-bound water, there is a fundamental possibility **for involving the volume of thin channels and capillaries in filtration.**

Pore channel size distribution

Proportion of pore channels in the fluid

CORE TESTING

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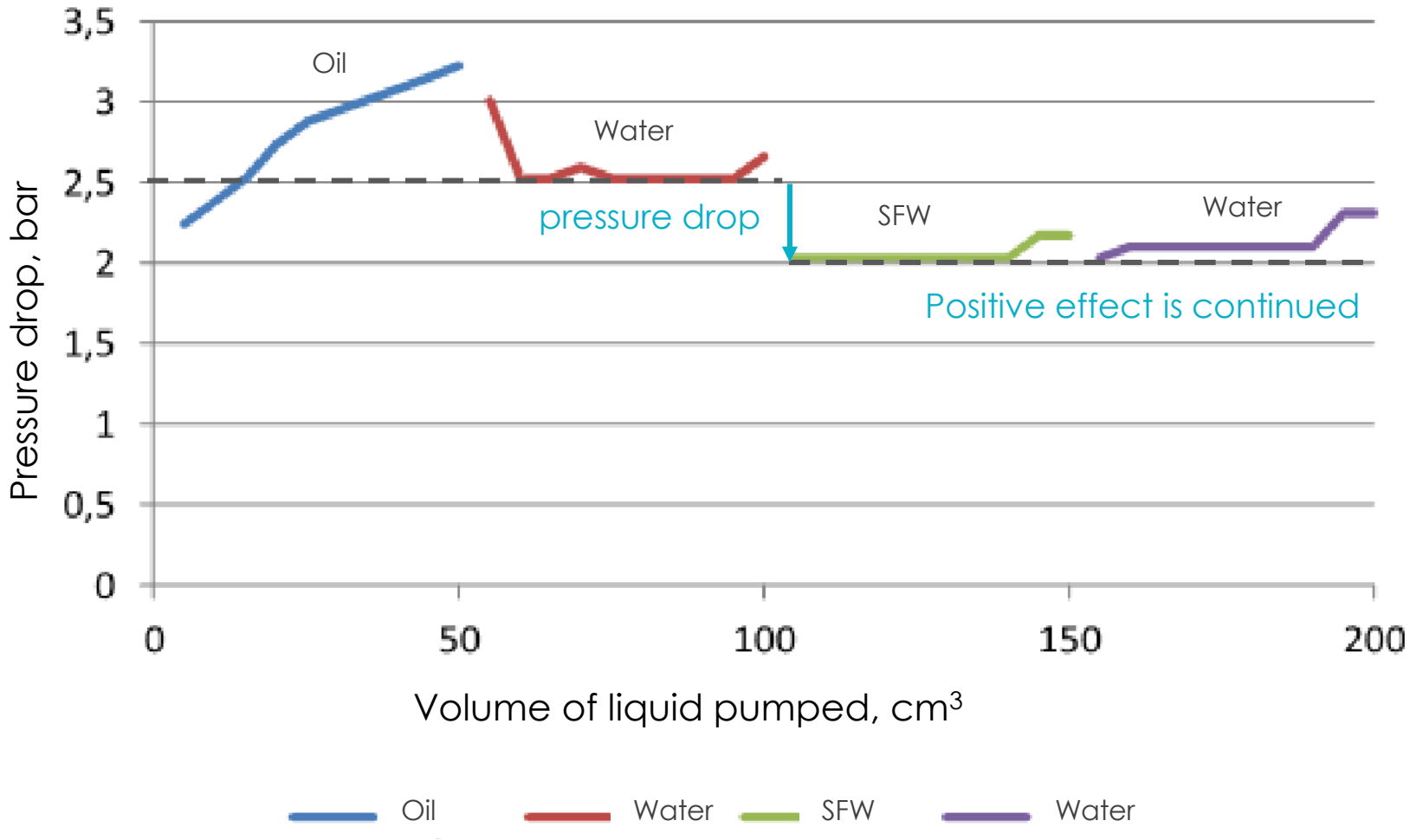

Core permeability: **61** mD

Purpose of the experiment:
To study the dynamics of changes in pressure drop during step-by-step pumping samples of liquids through the core:

1. Oil
2. Water
3. SFW
4. Water

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We conducted research on natural core using Core Lab equipment. Non-dimensional parameters were used for evaluation:

Resistance factor (RF)

the ratio of the mobility factor (μm²/mPa.s) of water before exposure to the mobility coefficient of the solution of the composition in a porous medium.

Since the mobility, like permeability, according to Darsi rule is inversely proportional to the pressure drop during filtration, at a constant filtration rate of liquid through the core, the resistance factor is equal to the ratio of the pressure drop during filtration of the liquid to the pressure difference in the filtration of water prior treatment, i.e. **RF = P_p / P_v**. When testing TerraFlow Type B, the resistance factor indicates the degree of pumpability of the liquid through a porous medium.

Residual Resistance Factor

is the ratio of the mobility of water before exposure to water mobility after exposure to the reagent,
i.e. **RRF = P'_v /P_v**

When testing the TerraFlow SFW liquid, RRF indicates the extent of change in the phase permeability for water.

Swelling Factor

indicates the extent of increase in filtration resistance during filtration of water after injection of the reagent compared to the same when filtering the reagent solution.
SF = P'_v / P_p.

WHAT DID THE EXPERIMENTAL DATA SHOW?

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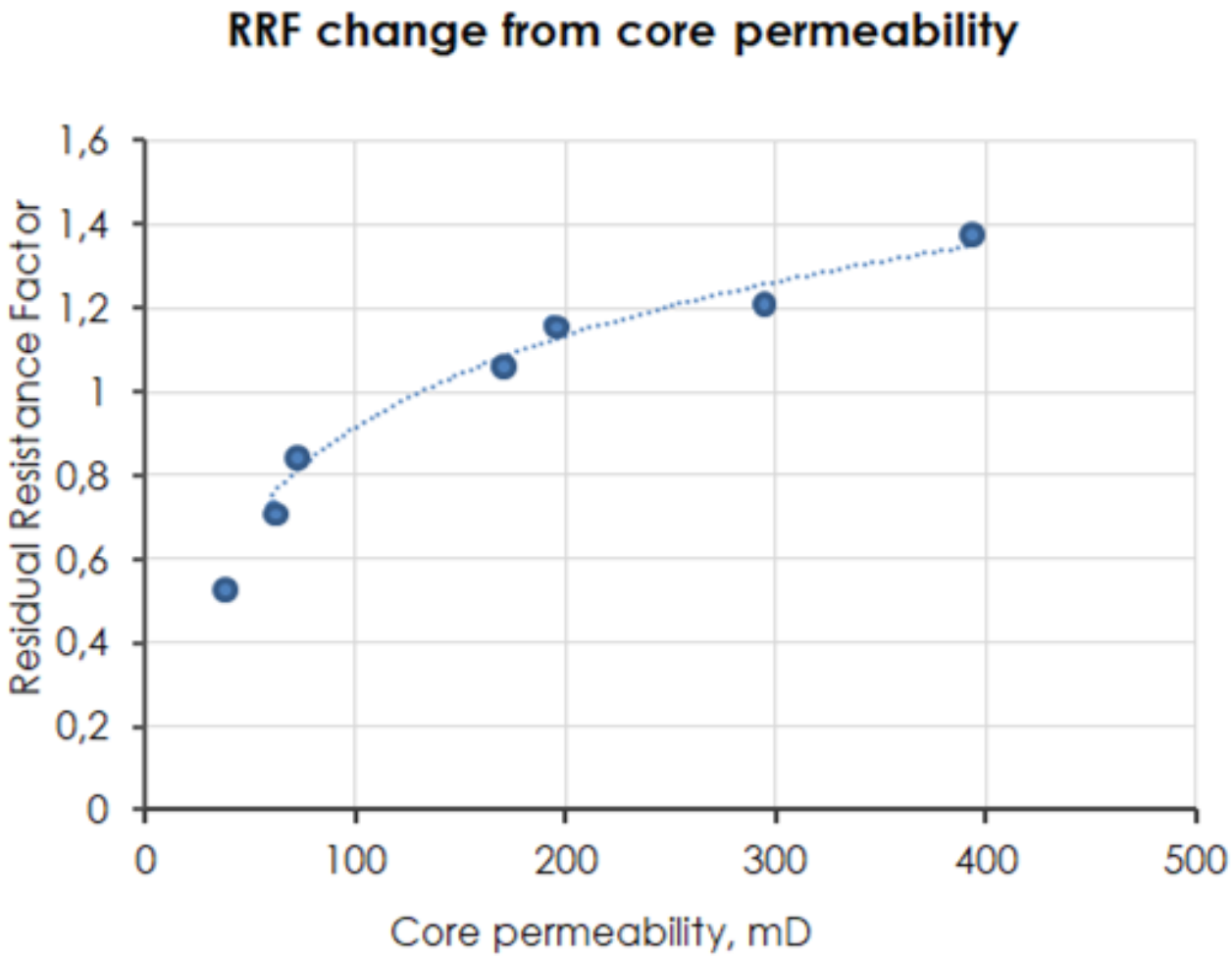

The strongest influence of TerraFlow SFW - on the change in phase permeability in low-permeability formations (less than 100 mD).

Residual Resistance Factor (RRF) value in this case is:

- 0,824 – for core sample 61 mD;
- 0,858 – for core sample 62 mD;
- 0,214 – for core sample 4 mD.

Experiment Conclusion:

1. After injection of TerraFlow SFW, an increase in water permeability is observed.

2. The filtration properties of the reservoir are preserved after injection. This indicated by the extent of increase in filtration resistances during water filtration after injection of the reagent (SFW) is close to or less than 1.

IMPLEMENTATION OF TERRAFLOW SFW AT THE WELL

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Technology Implementation Options
TerraFlow SFW

One-time treatment
(no more than 24 h)

Pumping Truck

Effect – more than 1 year. Additional oil production.

Used equipment:
Only pumping truck and 20 cub.m tank

Permanent adding in injected water

Dosing Pump

Stable effect that does not fade with time.
Increased Oil Recovery Factor at the waterflooding pattern.

Used equipment: dosing pump

OILFIELD DESCRIPTION. KAZAKHSTAN. SANDSTONE

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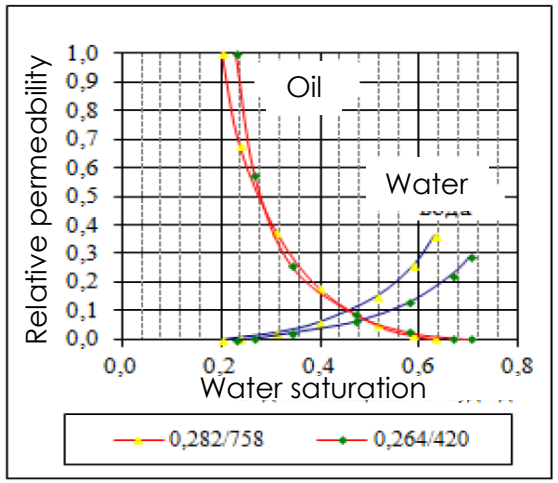
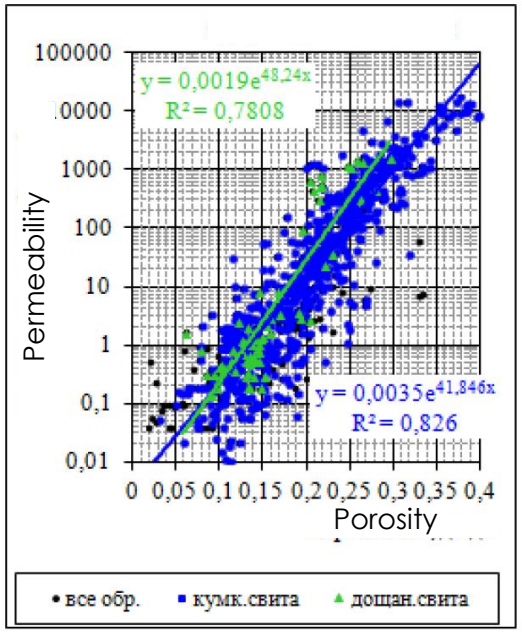
Physical and lithological characteristic of reservoirs by core

Boundary values of reservoir properties

Formation / Boundary values	Jurrasic	
	J-I, JI-V	J-IV-1
Permeability, mD	2	2
Porosity, %	16	14



Relative permeability curves for oil and water



Porosity vs. Porosity

PVT properties

Properties of reservoir oil

Parameters	Value
Saturation pressure, MPa	4.76
GOR, scf/stb	375,4
Volume coefficient	1,2
API gravity, °	60,2
Viscosity at reservoir conditions, cP	1,16

Properties of reservoir water

Parameters	Value
Density in stand. con., kg/m^3	1049,6
Water salinity, g/L	67,08
CL^- content, g/L	41,2
pH	7,04

Current reservoir pressure – 9,5 MPa

CASE 1: MAP (KAZAKHSTAN, SANDSTONE)

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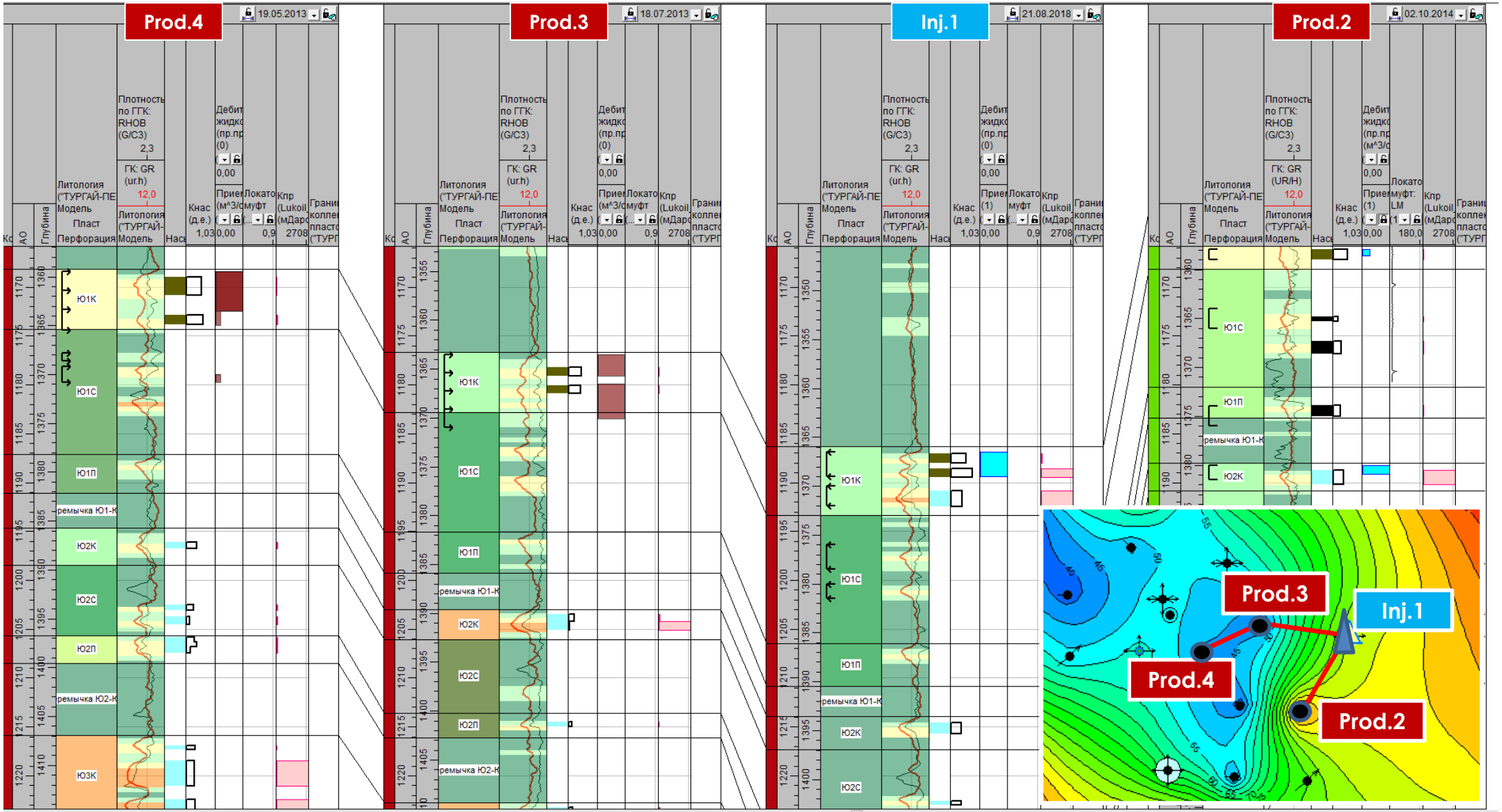

CASE 1: WELL PERFORMANCE (KAZAKHSTAN, SANDSTONE)

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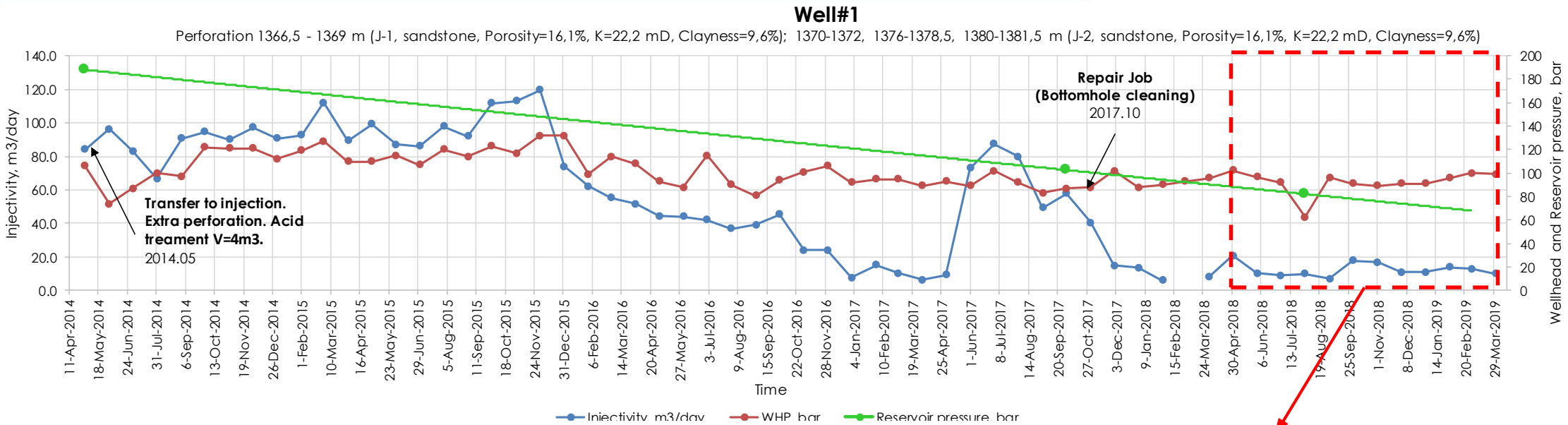
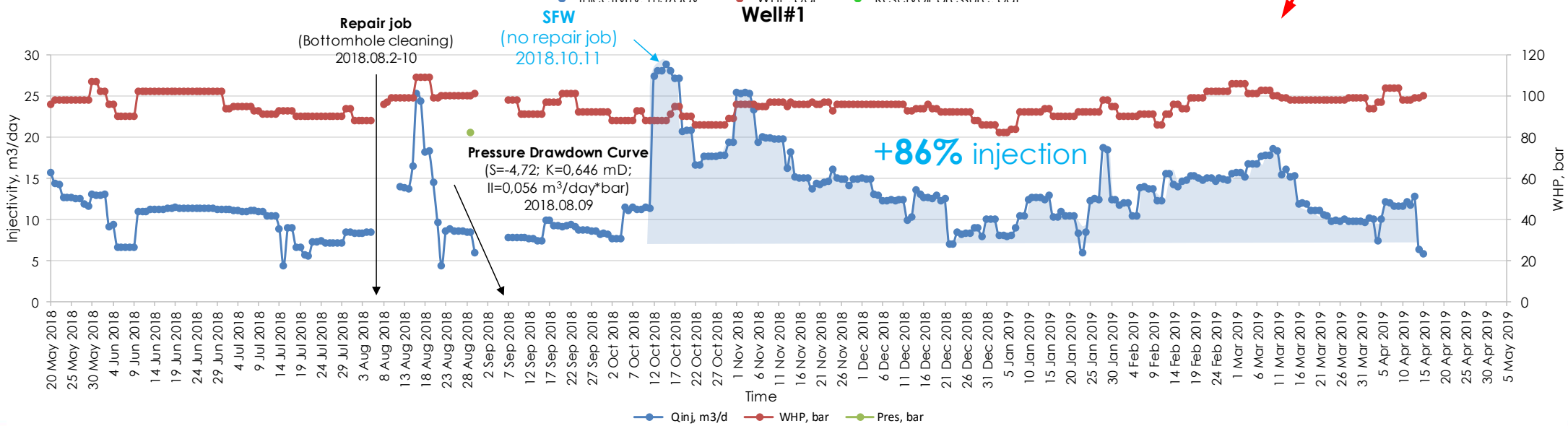
WELL STIMULATION TECHNOLOGIES





CASE 1: PLT - SCHEME (KAZAKHSTAN, SANDSTONE)

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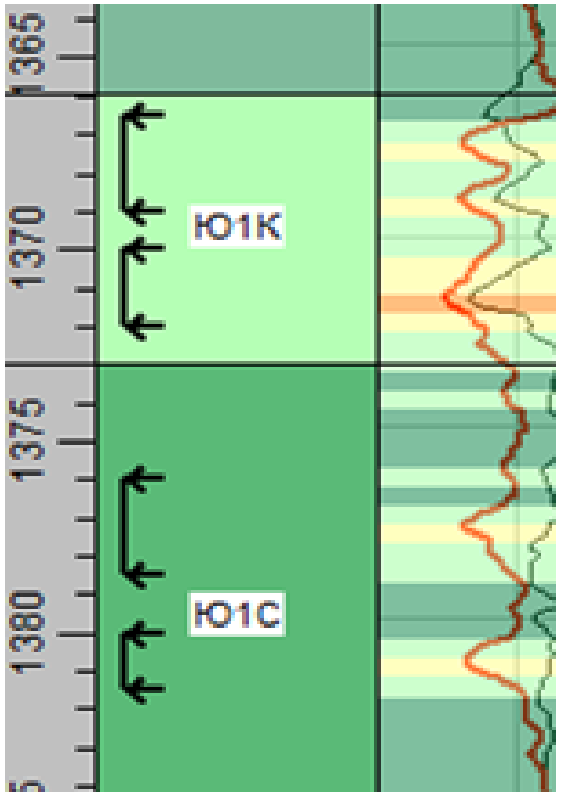
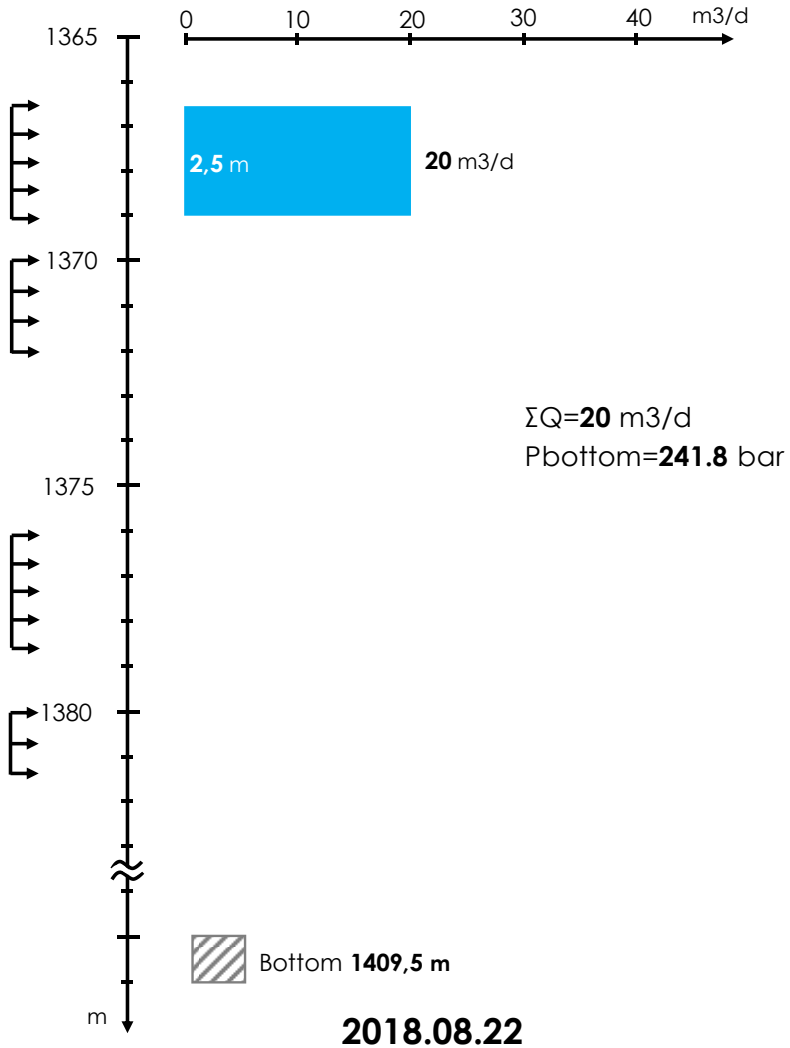


K=**20** mD

K=**5** mD

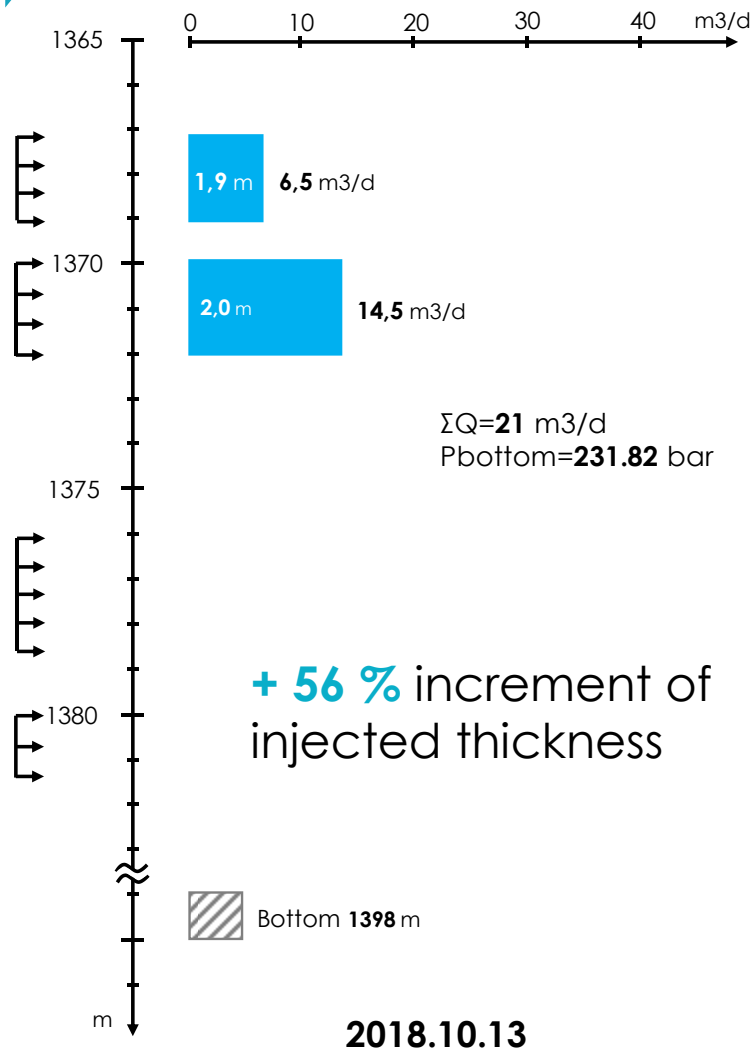
PLT
before SFW



ΣQ=**20** m3/d
Pbottom=**241.8** bar

2018.08.22

PLT
After SFW



ΣQ=**21** m3/d
Pbottom=**231.82** bar

+ 56 % increment of injected thickness

2018.10.13

CASE 1: PLT (KAZAKHSTAN, SANDSTONE)

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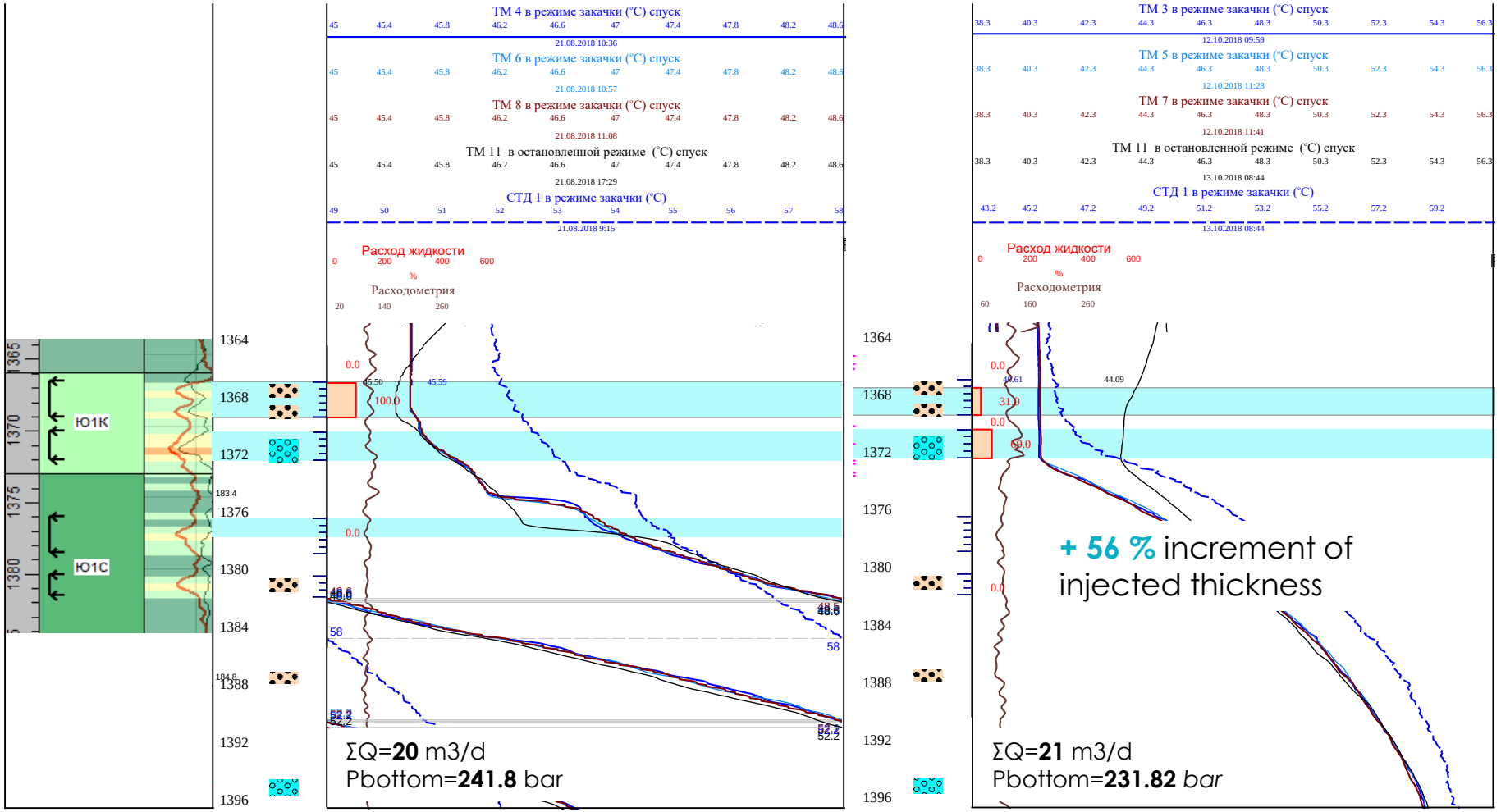
Profile

PLT before **TerraFlow SFW** (tool GEO-M6)
2018.08.22

PLT after **TerraFlow SFW** (tool GEO-M6)
2018.10.13



CASE 1: PRODUCTION WELLS RESPONSE

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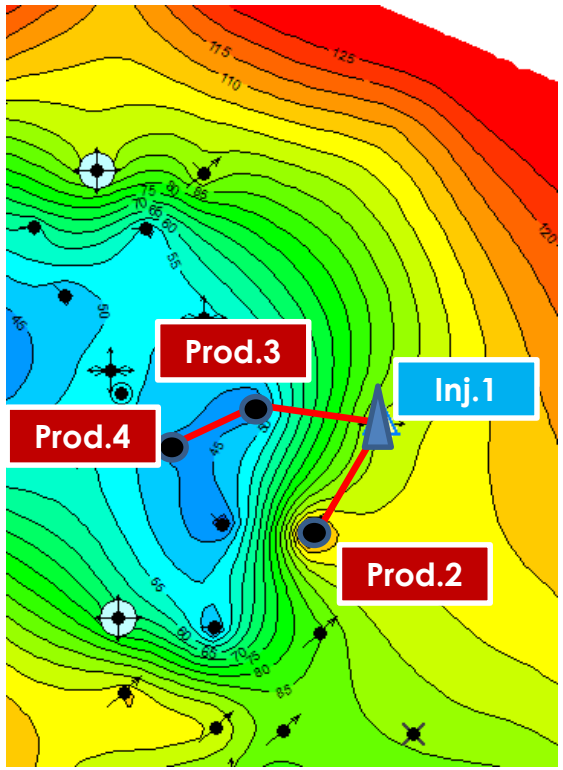

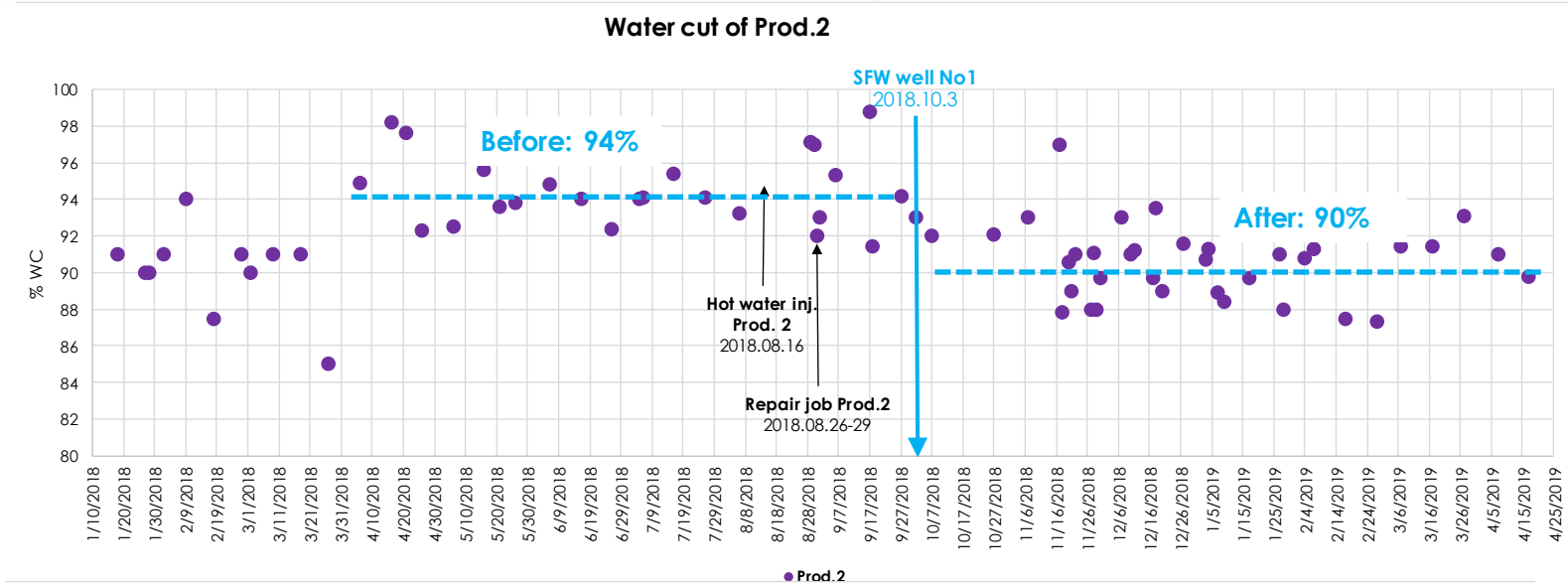

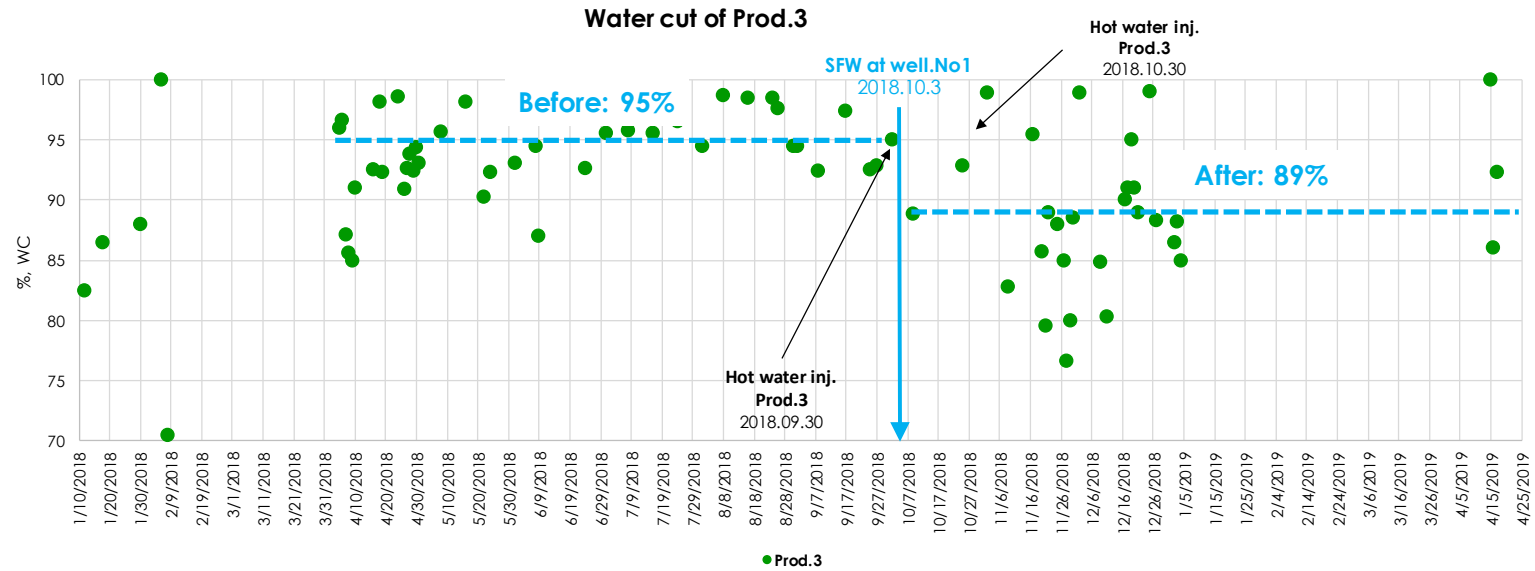

CASE 1: CONCLUSION

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Conclusion:

- Increasing Injectivity Index from **0.05** m^3/day*bar to **0.12** m^3/day*bar (during 30 days after SFW).
- **+ 56 %** (according to PLT before and after).
- Reduction of water cut in producers around(for Prod.3 from **95%** to **89%**, for Prod.2 from **94%** to **90%**).
- Additional accumulated oil production – **500 ton**.
- Duration of effect – more than **6 months.**

FEEDBACK 2019/05/20 (CUSTOMER 1)

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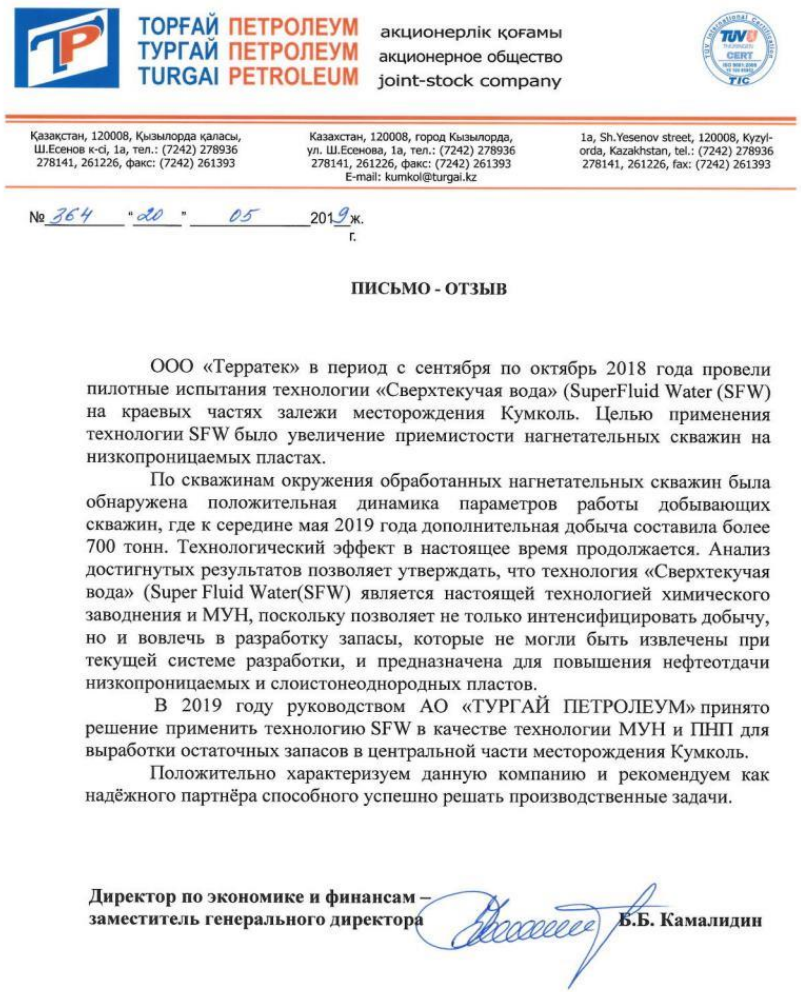

ТОРҒАЙ ПЕТРОЛЕУМ
ТУРГАЙ ПЕТРОЛЕУМ
TURGAI PETROLEUM
акционерлік қоғамы
акционерное общество
joint-stock company

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№ 364 "20" 05 2019 ж. г.

ПИСЬМО - ОТЗЫВ

ООО «Терратек» в период с сентября по октябрь 2018 года провели пилотные испытания технологии «Сверхтекучая вода» (SuperFluid Water (SFW) на краевых частях залежи месторождения Кумколь. Целью применения технологии SFW было увеличение приемистости нагнетательных скважин на низкопроницаемых пластах.

По скважинам окружения обработанных нагнетательных скважин была обнаружена положительная динамика параметров работы добывающих скважин, где к середине мая 2019 года дополнительная добыча составила более 700 тонн. Технологический эффект в настоящее время продолжается. Анализ достигнутых результатов позволяет утверждать, что технология «Сверхтекучая вода» (Super Fluid Water(SFW) является настоящей технологией химического заводнения и МУН, поскольку позволяет не только интенсифицировать добычу, но и вовлечь в разработку запасы, которые не могли быть извлечены при текущей системе разработки, и предназначена для повышения нефтеотдачи низкопроницаемых и слоистонеоднородных пластов.

В 2019 году руководством АО «ТУРГАЙ ПЕТРОЛЕУМ» принято решение применить технологию SFW в качестве технологии МУН и ПНП для выработки остаточных запасов в центральной части месторождения Кумколь.

Положительно характеризуем данную компанию и рекомендуем как надёжного партнёра способного успешно решать производственные задачи.

Директор по экономике и финансам – заместитель генерального директора **Б.Б. Камалидин**

003512

"…Producers around of the treated injectors were found to have a positive trend in the parameters of oil production, where by the middle of May 2019 **additional production amounted to more than 700 tons.** The technological effect is currently ongoing. Analysis of the achieved results confirms that the SFW technology is a real technology of chemical flooding and EOR, as it allows not only to intensify oil production, but also to involve into the development reserves that could not be recovered under current development system. SFW is intended to increase the oil recovery factor of low-permeable and multilayered inhomogeneous formations…"

CASE 2: INJECTOR (KAZAKHSTAN, SANDSTONE)

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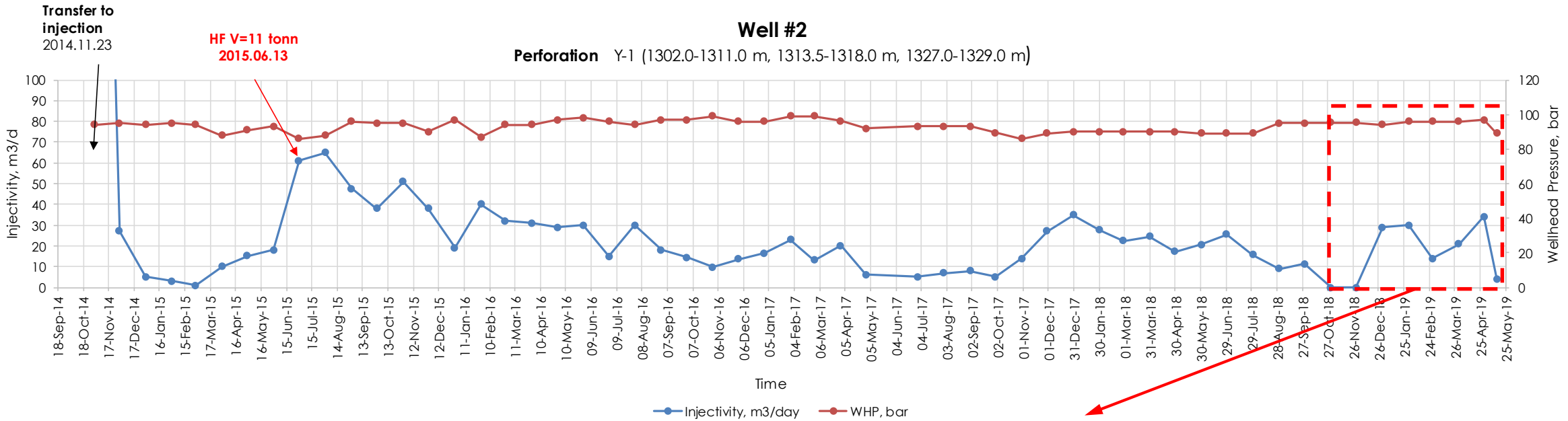

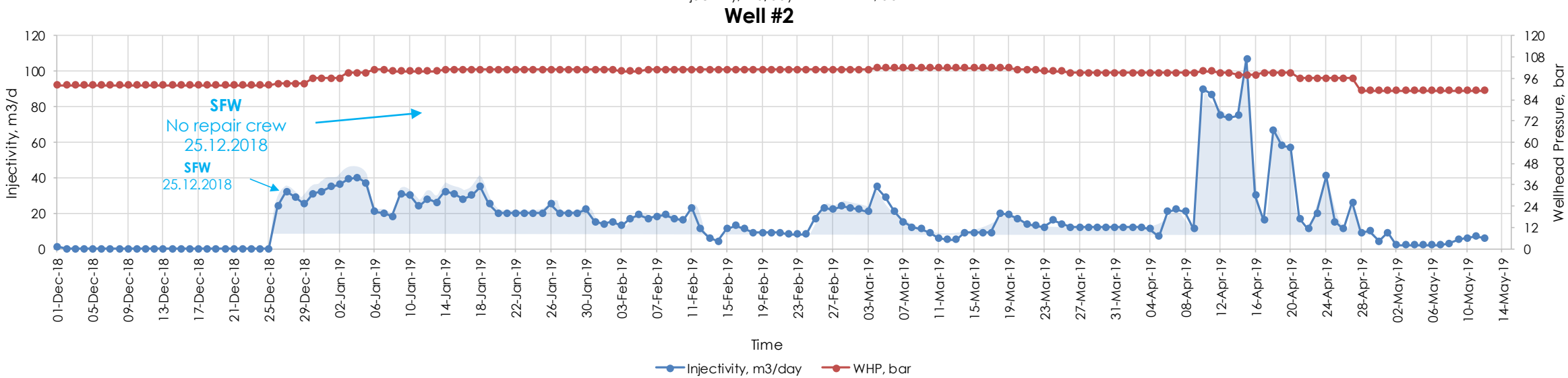

FEEDBACK 2018/02/11 (CUSTOMER 2)

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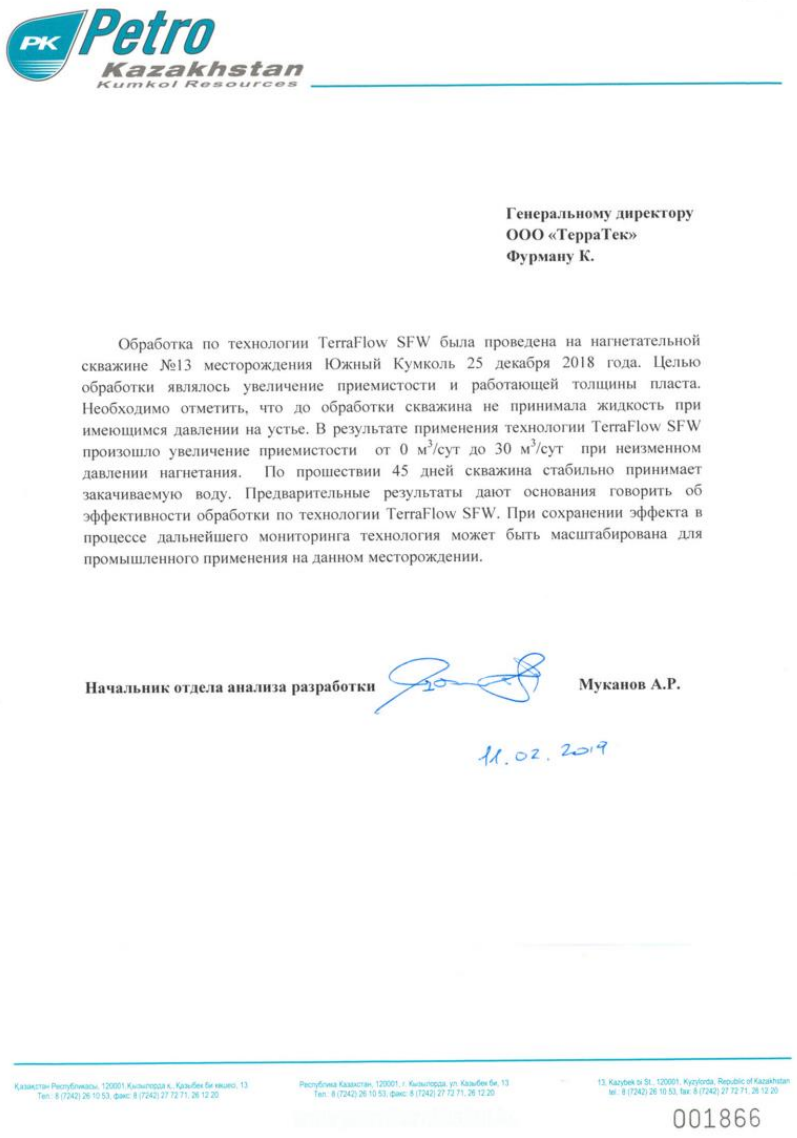

PK Petro Kazakhstan
Kumkol Resources

Генеральному директору
ООО «ТерраТек»
Фурману К.

Обработка по технологии TerraFlow SFW была проведена на нагнетательной скважине №13 месторождения Южный Кумколь 25 декабря 2018 года. Целью обработки являлось увеличение приемистости и работающей толщины пласта. Необходимо отметить, что до обработки скважина не принимала жидкость при имеющимся давлении на устье. В результате применения технологии TerraFlow SFW произошло увеличение приемистости от 0 м^3/сут до 30 м^3/сут при неизменном давлении нагнетания. По прошествии 45 дней скважина стабильно принимает закачиваемую воду. Предварительные результаты дают основания говорить об эффективности обработки по технологии TerraFlow SFW. При сохранении эффекта в процессе дальнейшего мониторинга технология может быть масштабирована для промышленного применения на данном месторождении.

Начальник отдела анализа разработки **Муканов А.Р.**

11.02.2019

001866

“
…Treatment using the SFW technology was executed at well No.13 of the South Kumkol field on December 25, 2018. The purpose of the treatment was to increase the injectivity and working thickness of the formation. It should be noted that **before the treatment, well did not have injectivity with the existing wellhead pressure**. As a result of SFW technology application, the injectivity increase from 0 m^3/day to 30 m^3/day with a constant wellhead pressure. After 45 days, the well has constant injectivity. Preliminary results give grounds to speak about the efficiency of treatment using SFW technology. While remaining the positive effect during further monitoring, the technology can be scaled for industrial use in a given field…
”

CASE 3: WELL PERFORMANCE (KAZAKHSTAN, SANDSTONE)

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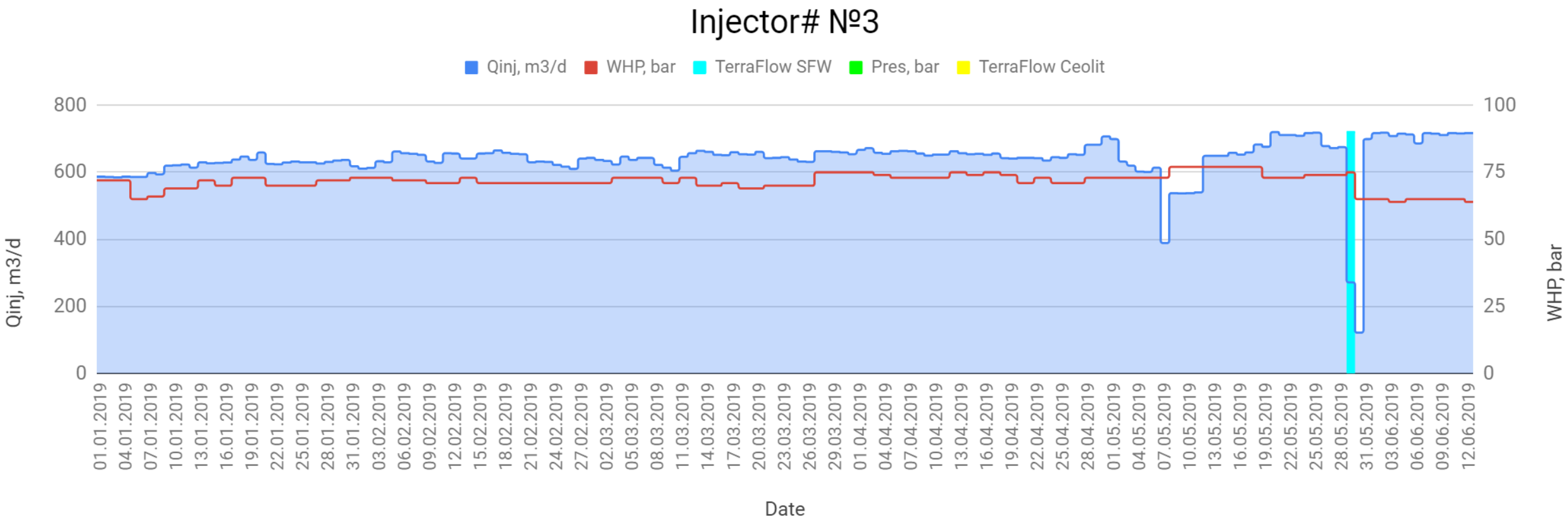

CASE 3: PLT - SCHEME (KAZAKHSTAN, SANDSTONE)

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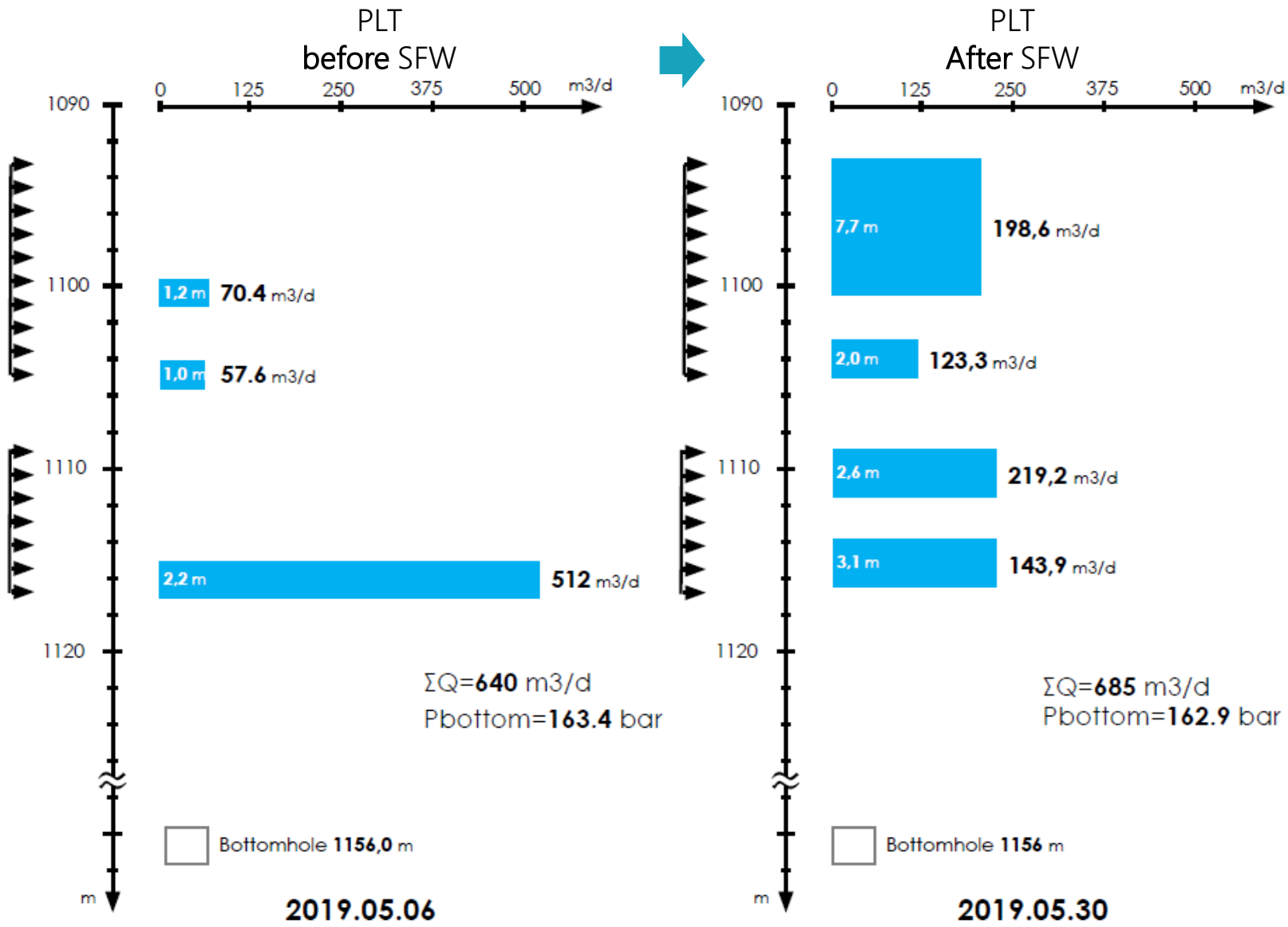

Good well candidates for SFW technology:

1.Technology is intended for reservoirs with high layered heterogeneity and average permeability along the section **less than 100 mD**.

2. The effectiveness of the technology **has been proven** in field conditions **for terrigenous reservoirs**, including reservoirs with a high wettability. The effectiveness of technology **for carbonate reservoirs** is **proven in the laboratory**, but the field experience is negligible.

3. TerraFlow SFW technology is recommended **for interlayers** with range of permeability **0.5 - 50 mD**.

4. Also this technology is recommended for injectors with under compensation of injection around it.

5. The use of technology is possible in both depleted areas with a **water cut** of production wells **up to 99%** and in new areas.

6. Reservoir temperature - **up to 120 deg C**.

7. Reservoir pressure - **no limits**.

8. Salinity of injected water – up to **200 g/l**.

ADVANTAGES OF APPLICATION

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WELL STIMULATION TECHNOLOGIES

In the low-permeability reservoirs, this technology has **no analogs** in oil displacement efficiency.

SFW Technology – key advantages:

- Does not require the special hi-tech equipment and personnel;
- Has an ultra-low concentration at high efficiency;
- Mixing into injecting water at a group pumping station;
- Does not damage the reservoir in case of incorrect calculation the concentration of active agent;
- Does not harm the environment;
- Does not have ambient or reservoir temperature restrictions for the application;
- Non-corrosive;
- Continues to work effectively even with re-circulation in the injection system;
- Lower reservoir permeability - higher efficiency of the active agent;
- Has no competitors in terms of "price-quality".

SFW technology – application effects:

- **Increase of oil production** – not less than 15 %;
- **Increase in injectivity** of injection wells;
- **Reduce of watercut** – up to 20% (as for the basic values before implementation).
- **Average effect duration** – 1 year.

Conducted trials:

ТОРҒАЙ ПЕТРОЛЕУМ
ТУРГАЙ ПЕТРОЛЕУМ
TURGAI PETROLEUM

PK Petro Kazakhstan

ROSNEFT

Preparing for trials:

LUKOIL OIL COMPANY

GAZPROM NEFT

PETRONAS

النفط والغاز
PETROGAS E&P

E&P ӨзенМұнайГаз
АКЦИОНЕРЛІК ҚОҒАМЫ АКЦИОНЕРНОЕ ОБЩЕСТВО

Terratec LLC
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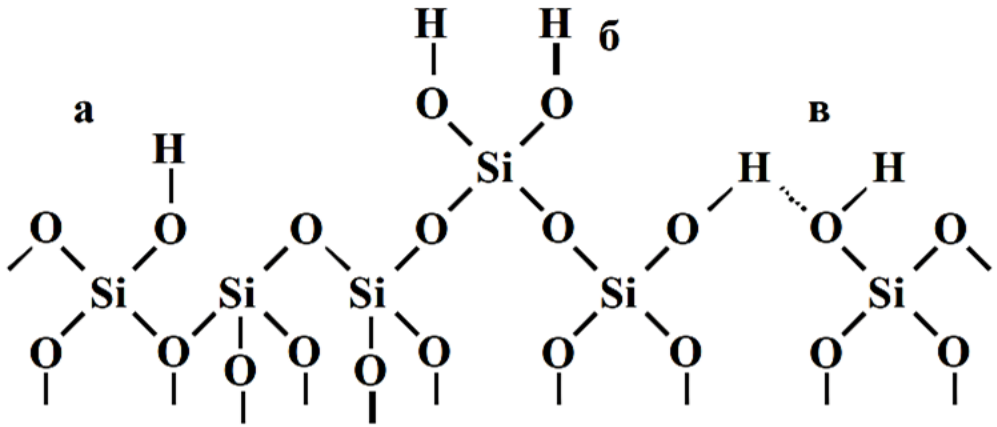
WATER ADSORPTION ON SILICA SURFACE

TERRATEC
WELL STIMULATION TECHNOLOGIES

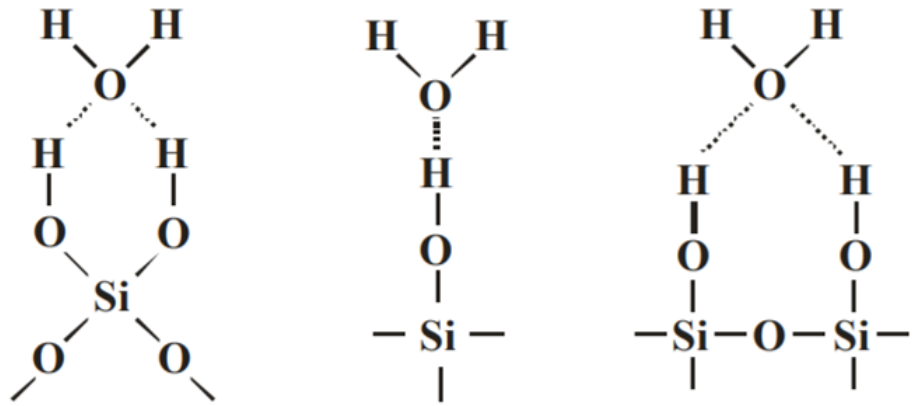
Schemes of possible surface OH-groups

(by A.V. Kiselev)



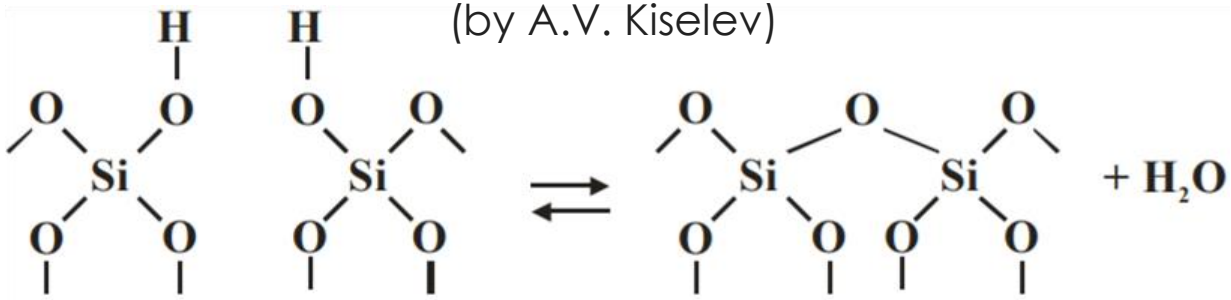
a)free silanol groups; b)disilanol groups; c) bind silanol groups

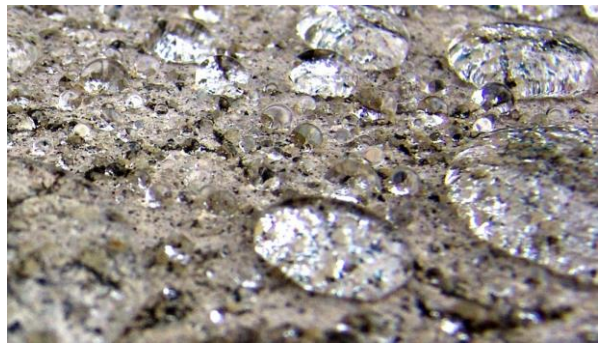
H-link mechanism



Isolation of water from the surface of a given silica particle

(by A.V. Kiselev)





Separation of OH-groups leads to hydrophobization of the silica surface

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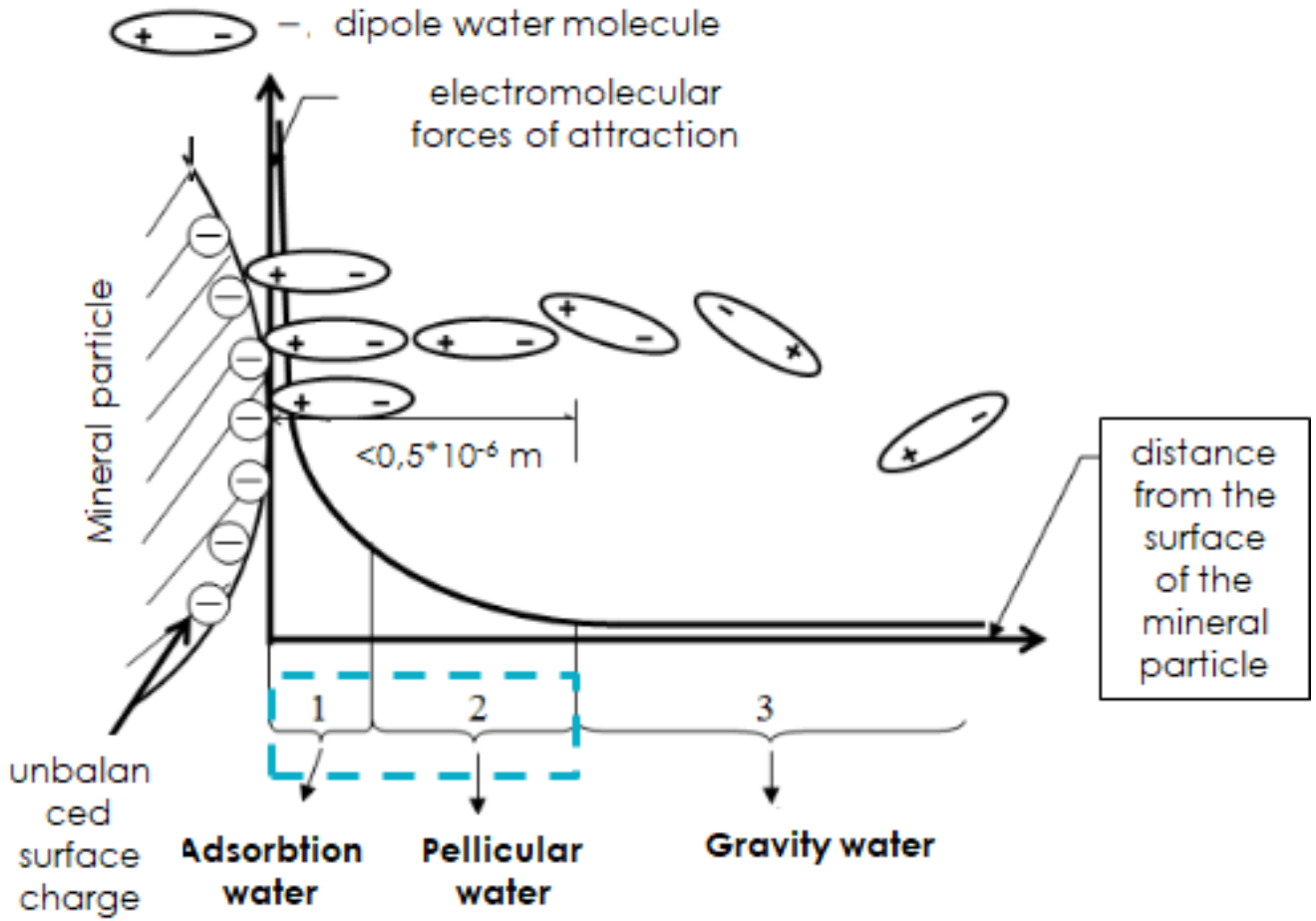
Types of water at the boundary with a solid



Properties	Gravity water	Bound Water
1)Viscosity	1) η_0	1) $\eta=1,1\div1,6\cdot\eta_0$
2) Dielectric constant	2) ε_0	2) $\varepsilon=0,04\div0,025\cdot\varepsilon_0$
3)Density	3) ρ_0	3) $\rho=0,02\cdot\rho_0$
4)Heat capacity	4) C_0	4) $C=1,25\div1,35\cdot C_0$
5)Surface tension	5) σ_0	5) $\sigma=K\cdot r$ (K – coefficient proportionality; r – radius of curvature of the tension surface)

Laplace formula
(capillary pressure)

$$\Delta p_c = \frac{2\sigma cos\theta}{r_c}$$

σ – surface tension
θ – contact angle
r_c – capillary radius

To create a movement of bound water in the capillary, it is necessary to overcome the capillary pressure.

TERRAFLOW SFW: HOW IT WORKS

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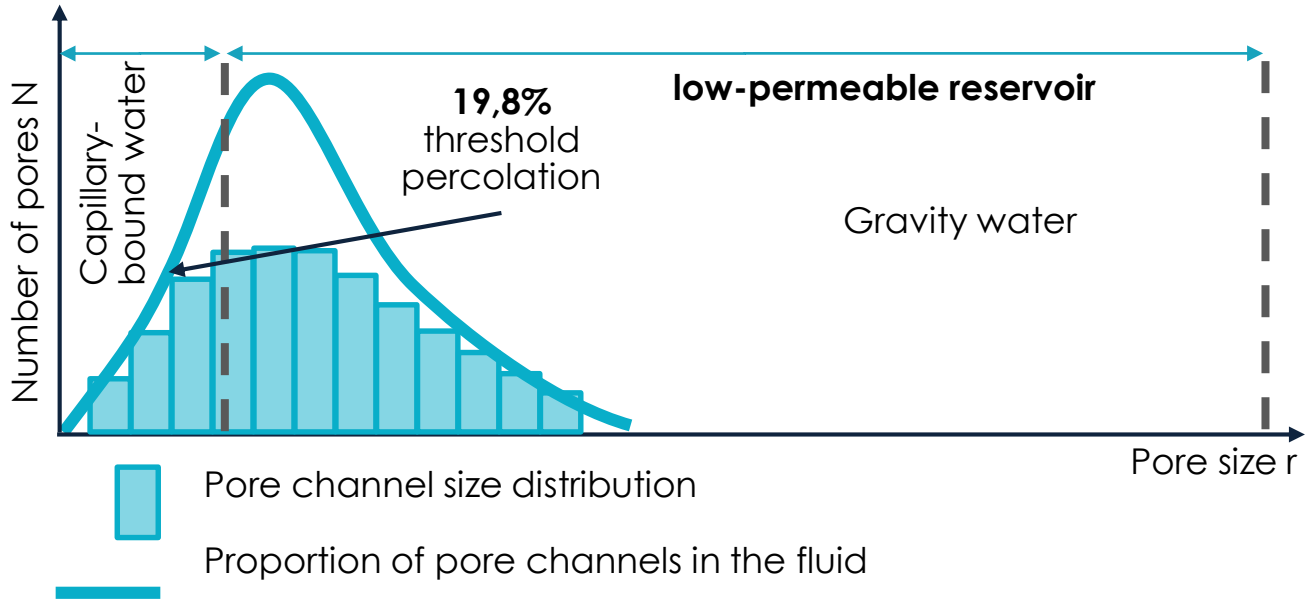
Low permeability reservoir:

The main share of flow channels contains **capillary-bound water.**

Mechanism of TerraFlow SFW:
stabilize the surface structure of the pore space due to the adsorption of the active component.

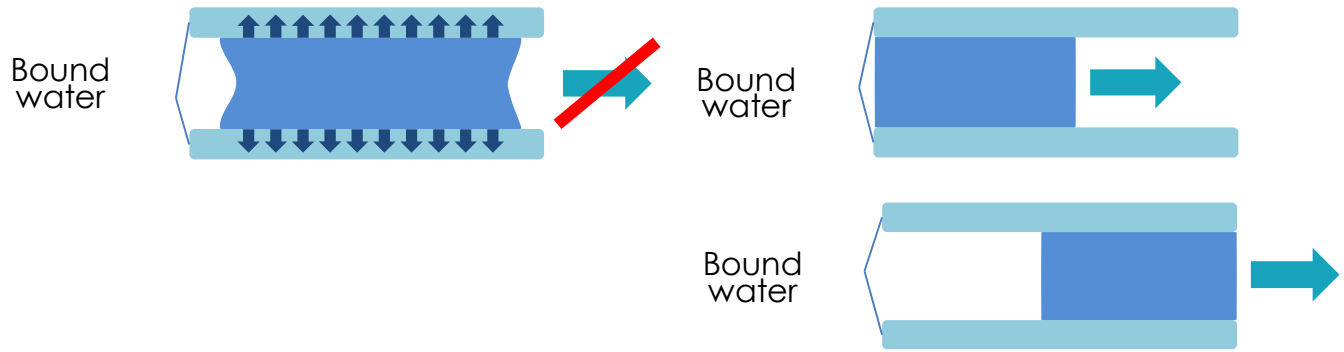
TerraFlow SFW technology **unlocks** capillary-bound water in oil-saturated formations and makes it mobile.

Your result:
Re-extraction of reserves previously blocked in **channels with low permeability**, which leads to an increase in oil production.



Case 1
(flooding)

Case 2
(flooding with **TerraFlow SFW**)



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