MIOR – Microbial Improved Oil Recovery

also known as

MEOR - Microbial Enhanced Oil Recovery

- Methodology
- Application
- Case Histories

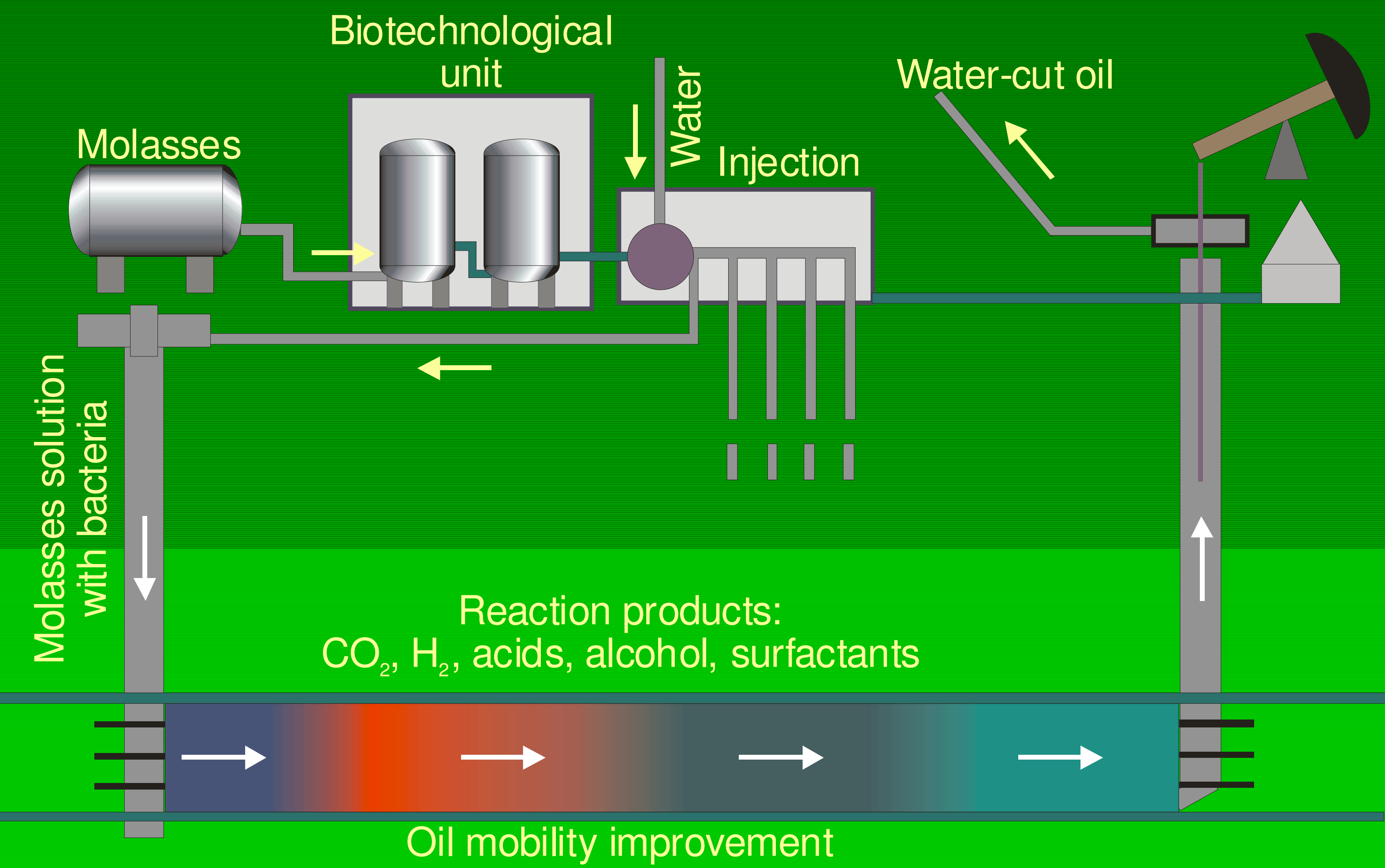
Classification of EOR - Technologies

- In-situ combustion
- Steam injection
- Gas injection
- Water injection
- Water injection with:
  - CO_2
  - Detergents
  - Polymer
  - Acids
  - Bacteria (MEOR)

Microbial Enhanced Oil Recovery

MEOR is an in-situ flooding method under exploitation of specific microorganisms synthesizing various products which enhance the oil recovery.

MEOR - Flow Diagram



Fermentation products of Clostridium tyrobutyricum, Strain R6 (mg/l)

methyl alcohol	213
ethyl alcohol	2.378
acetone	124
propyl alcohol	402
butyl alcohol	393
i-amyl alcohol	673
acetic acid	1.996
propionic acid	909
i-butyric acid	413
n-butyric acid	7.762
hydrogen	40 - 70 ml /g molasses
carbon dioxide	300 - 330 ml /g molasses

Microbial Insitu Activities - Biogas

Microbial Products	which changes	Oilfield Parameters
Bio-gas:		
CO_2 (80 %), H_2 (20 %) up to 380 ml per gram of molasses,	increases the pressure up to 20 bar in model experience	leads to a higher energy potential in the oil field
CH_4 as final product from organic acids, alcohol's and hydrogen	increases the oil volume factor and therefore decrease the oil viscosity	to give a better oil mobilization
	changes the pressure Potential in fissures and pores	increases the oil production rate

Microbial Insitu Activities - Organic Acids

Microbial Products	which changes	Oilfield Parameters
Organic acids:		
acetic-, propionic-, nutyric-, valerianic acid	decrease the pH up to 4.8	increase the per- meability of the rock
	dissolve the carbonate rock by about 0,2 tons of rock per ton of molasses	partially including of fresh not yet drained rock sessions to the fissure system building up new ways of flow

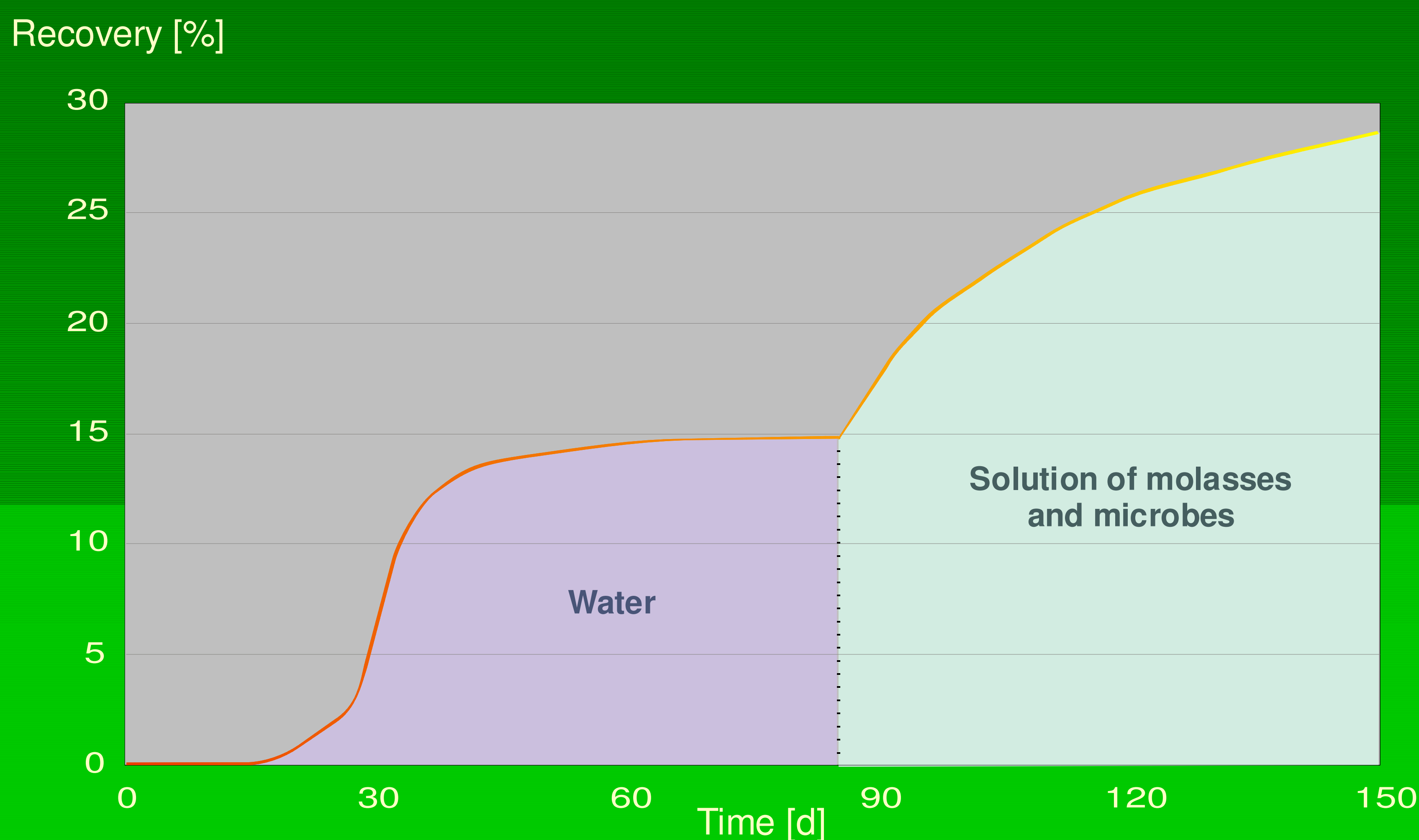
Microbial Insitu Activities - Acetone and Alcohol

Microbial Products	which changes	Oilfield Parameters
acetone and alcohol's:		
methanol, ethanol, propanol, butanol biolipids	decreasing the inter-facional tension for example against heptane up to 12 - 46,5 mNm-1 alternated the rock wettability	forces the imbibition of injected, fermented molasses media into the pore canals and fissures to give more oil from the rock break up oil/water barriers and emulsions lead to a better fluid rate

Basics of Microbial Improved Oil Recovery

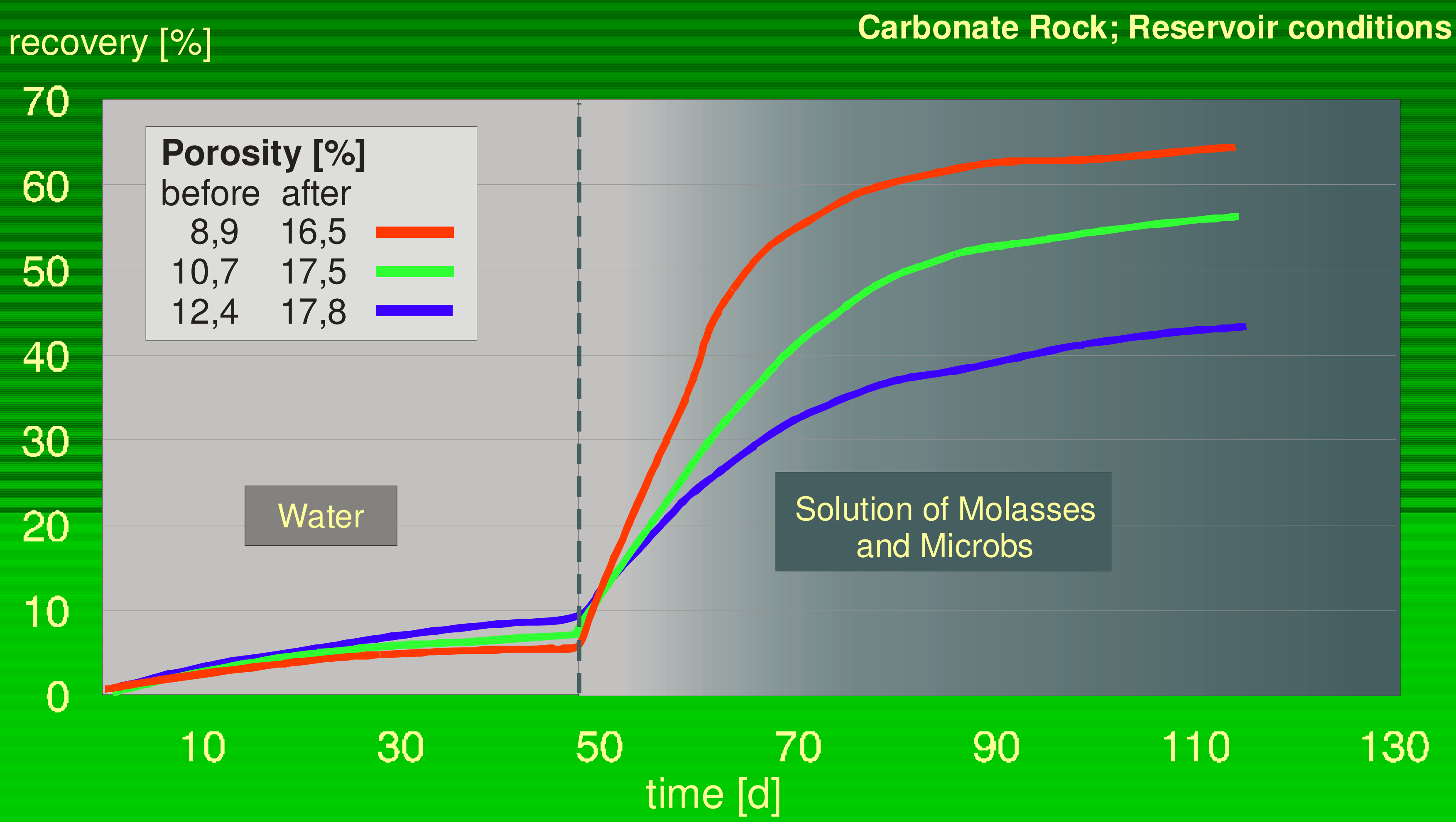
- Energy due to in-situ biogas formation
- Change in pressure potential in fissures and pores
- Decrease in viscosity of oil by increase in volume and hydrogenization
- Change in border surface tension oil/water
- Improvement of capillary adsorption of medium
- Increase of permeability, bringing in fresh matrix by rock solution

MIOR Core-Flooding



Porosity = 10 %, Oilsaturation = 79 %, Viscosity= 58 mPas, PV flooded= 0,25/d

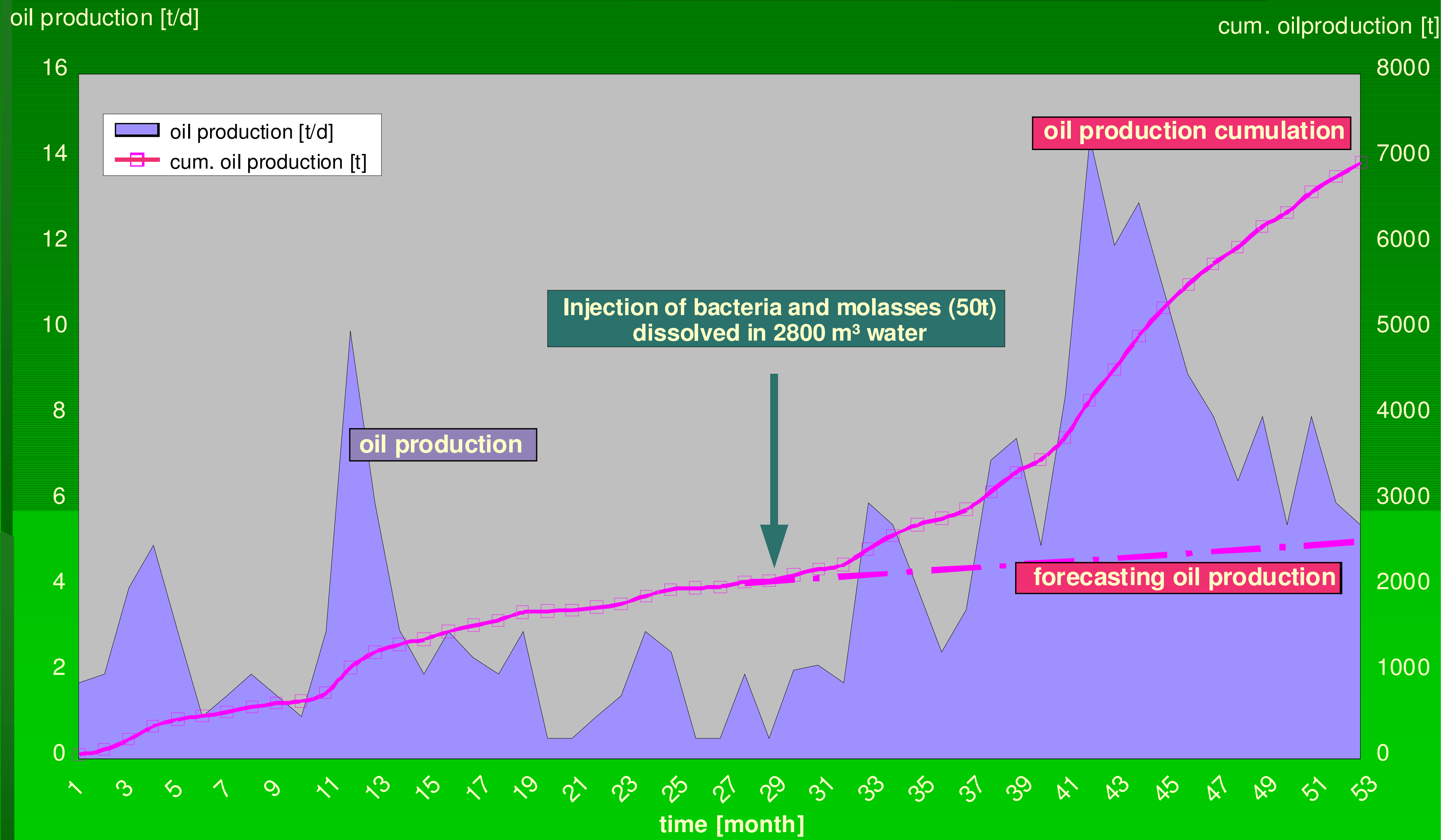
MIOR Imbibition Tests



Reservoir Characteristics “ Döbern ”

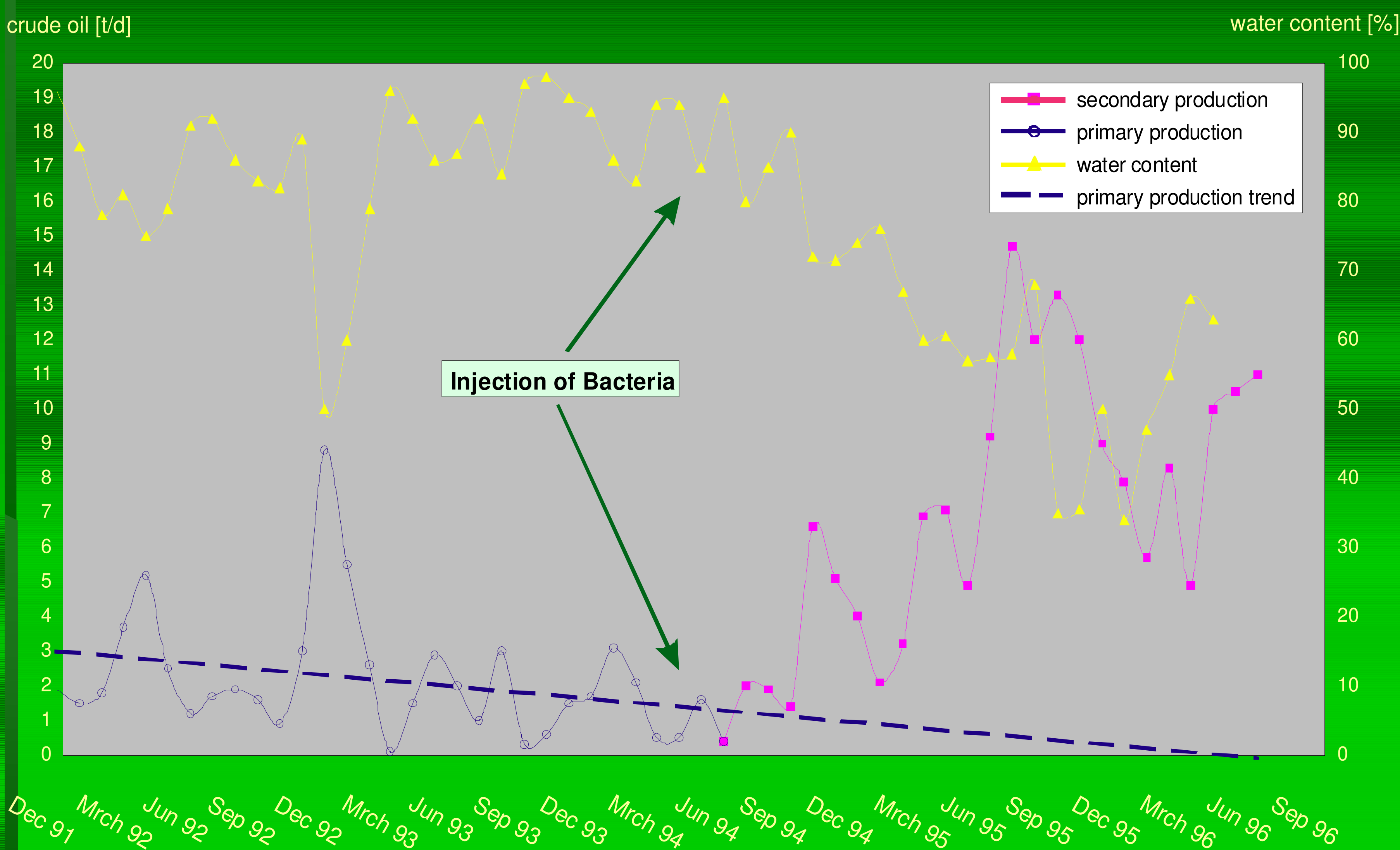
Depth	1240 m
Formation temperature	53 °C
Formation pressure	8 MPa
Formation water – NaCl-type	320g/L
Carbonate reservoir	Fissured-porous
Matrix porosity	1 - 2 %
Fissure porosity	0,1 - 0,5 %
Fissure permeability	10 - 50 mD
Oil density	0,84 g/cm³
Viscosity	6,3 mPa * s

MIOR Flooding on Oilfield Döbern (Germany)

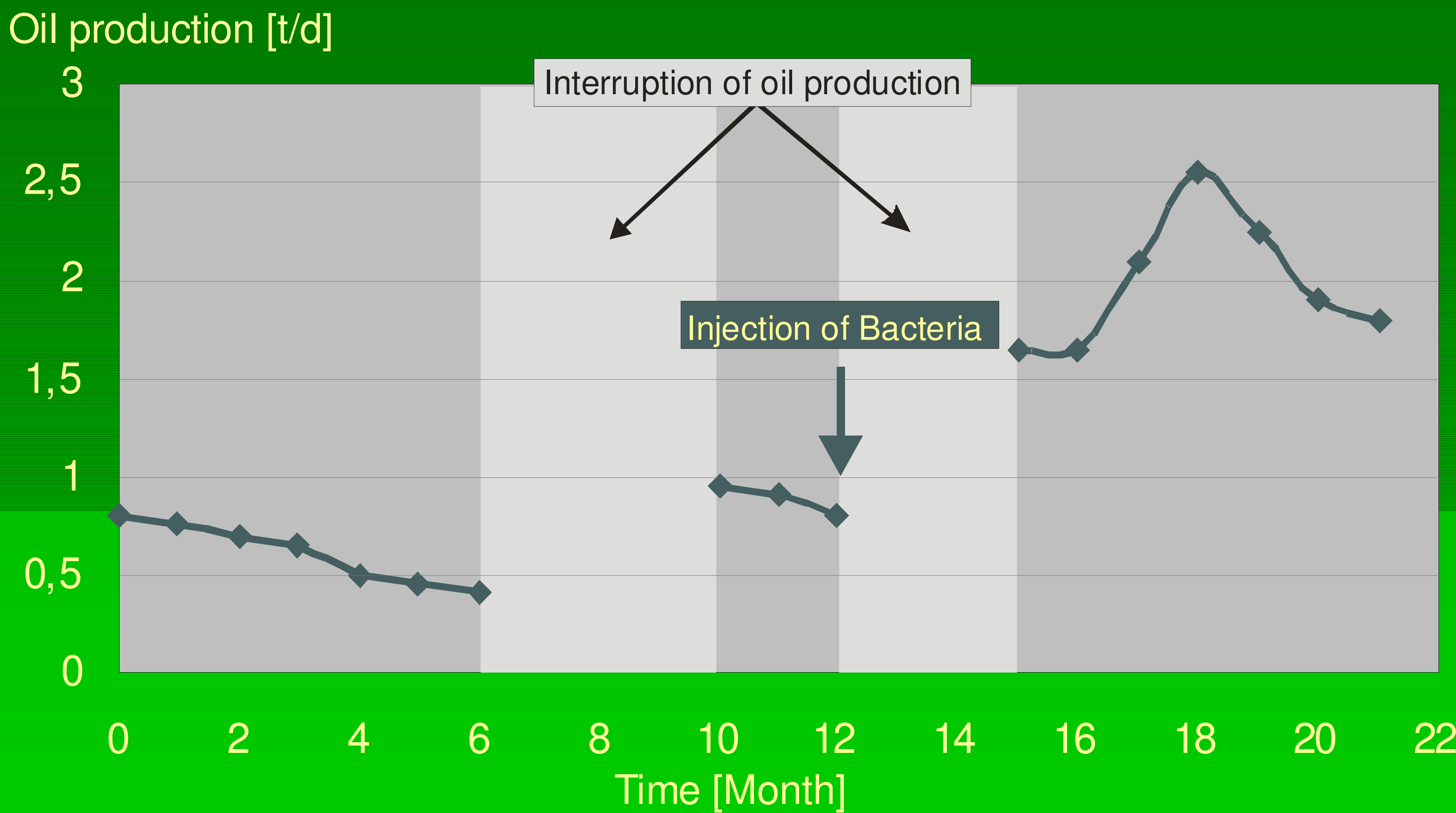


Fissured porous dolomite, T=55°C, Saltcontent= 310 g/l

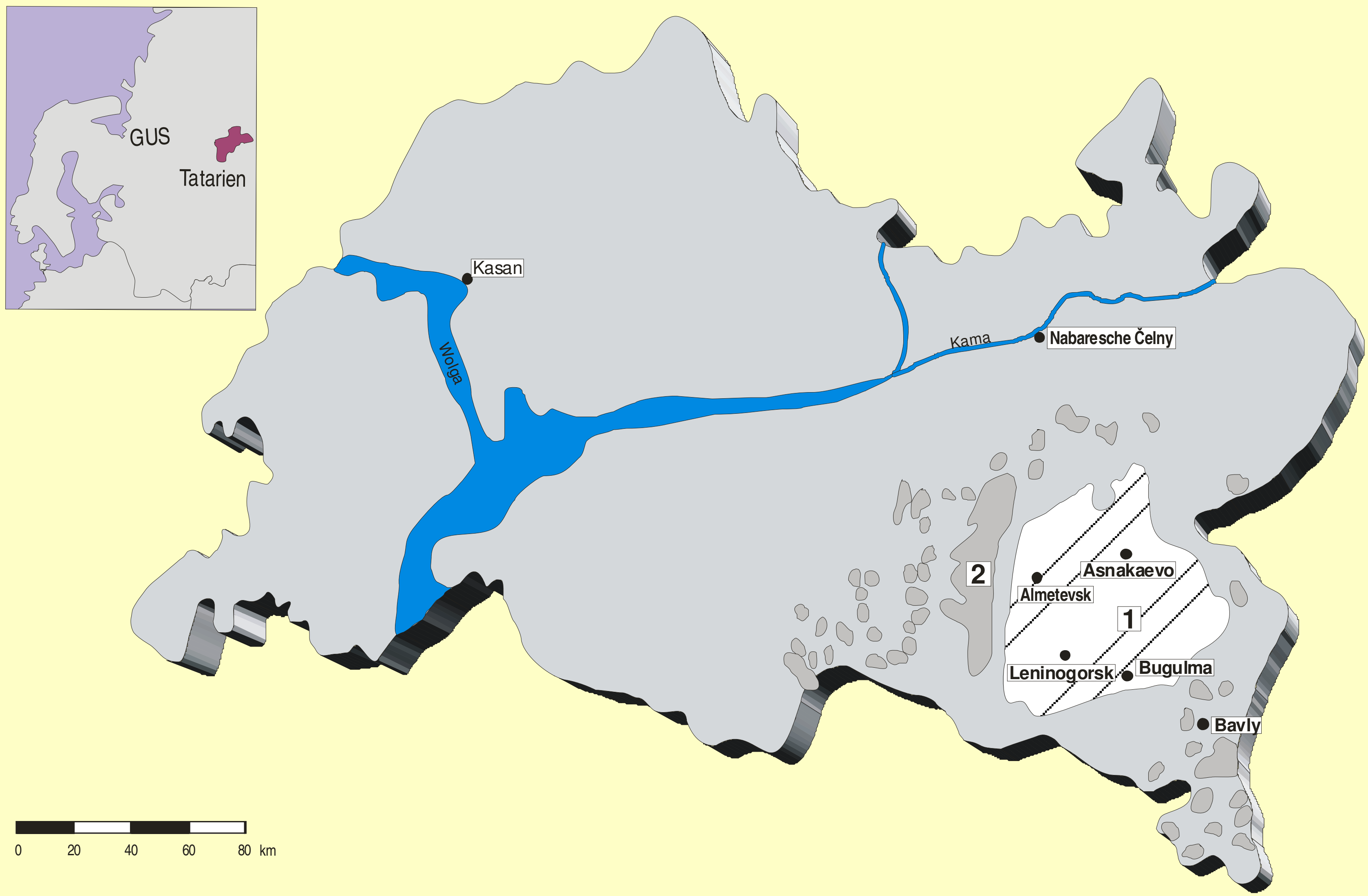
Daily Production Before and After MIOR



Huff and Puff an Oilfield “Döbern” (G)



Pilot Field Romashkino - Tatarstan

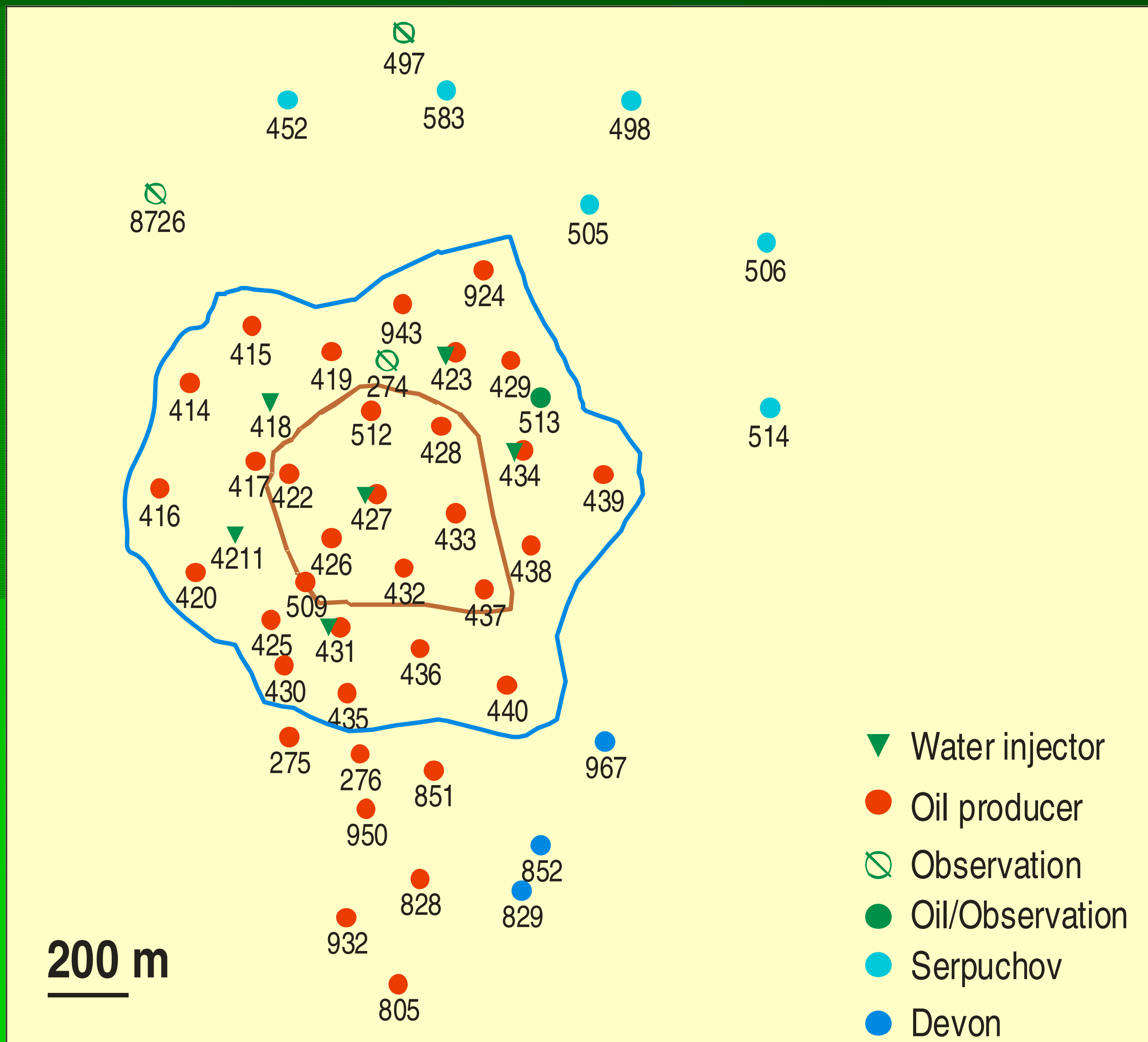


Field Trial – "Romashkino"

- Based on intensive scientific research (4 years) the field trial "Romashkino" was carried out in an industrial stage (1992-1994).

- **Daily Oil Production** **16,5 m³/operating day**
- **Daily Fluid Production** **38,0 m³/operating day**
- **Average Fluid Rate** **1,6 m³/well x operating day**
- **Producers operating** **24**
- **Injectors operating** **6**

Injection and Production wells



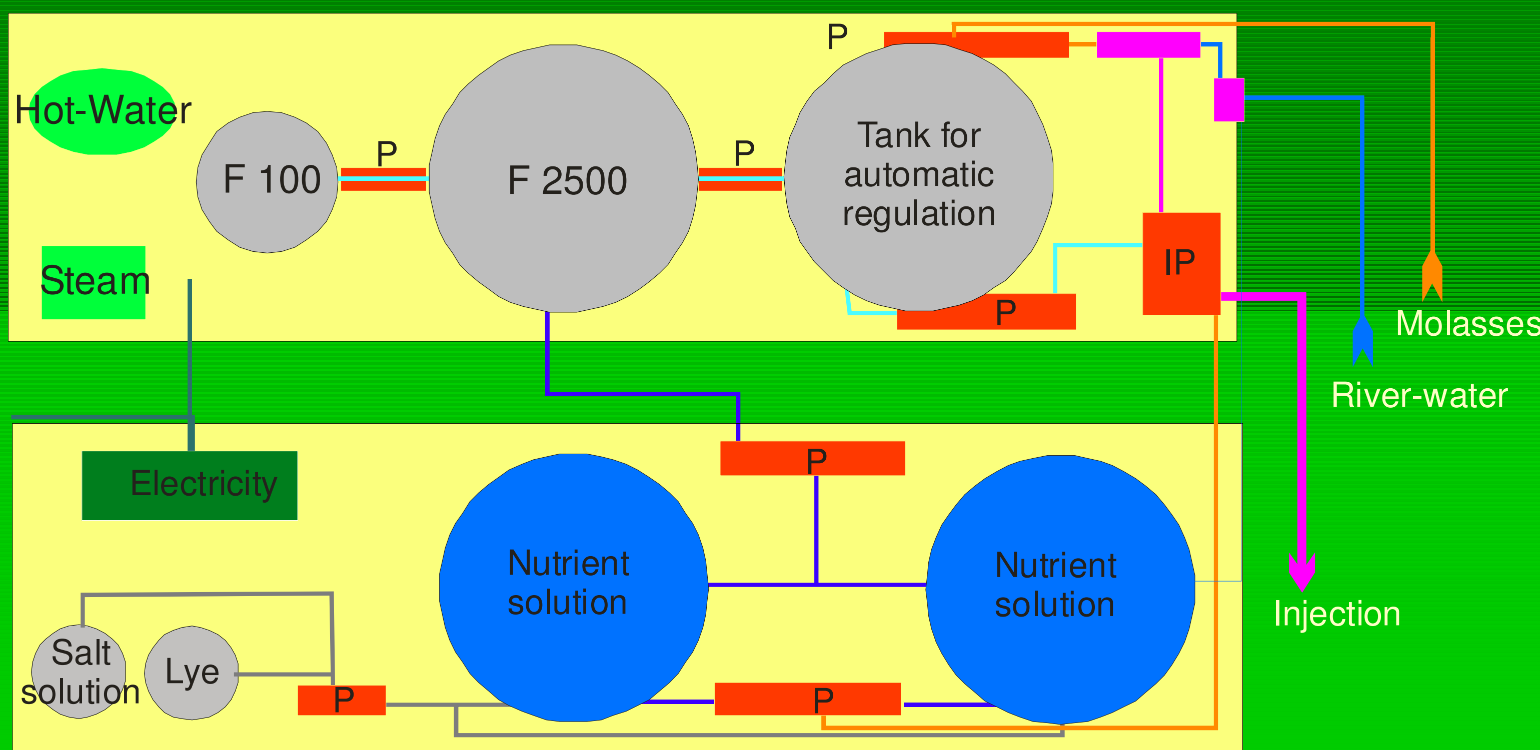
Characteristics of Bashkirian Reservoirs – Pilot field

Top Reservoir	493-515 m (selected)
Productive area	1.070,000 m²
Reservoir Rock	organic limestone
	fissured-porous
Average Porosity	9,8 %
Average net Thickness	5,7 m
Current Reservoir Pressure	6 - 7 MPa
Reservoir Temperature	21 °C
Oil Density	0,903 g/cm³ (25 API)
Oil Viscosity	50 - 80 m Pas
Gas-Oil-Ratio	3,2 Nm³/m³
Brine Salinity	30 - 40 g/l

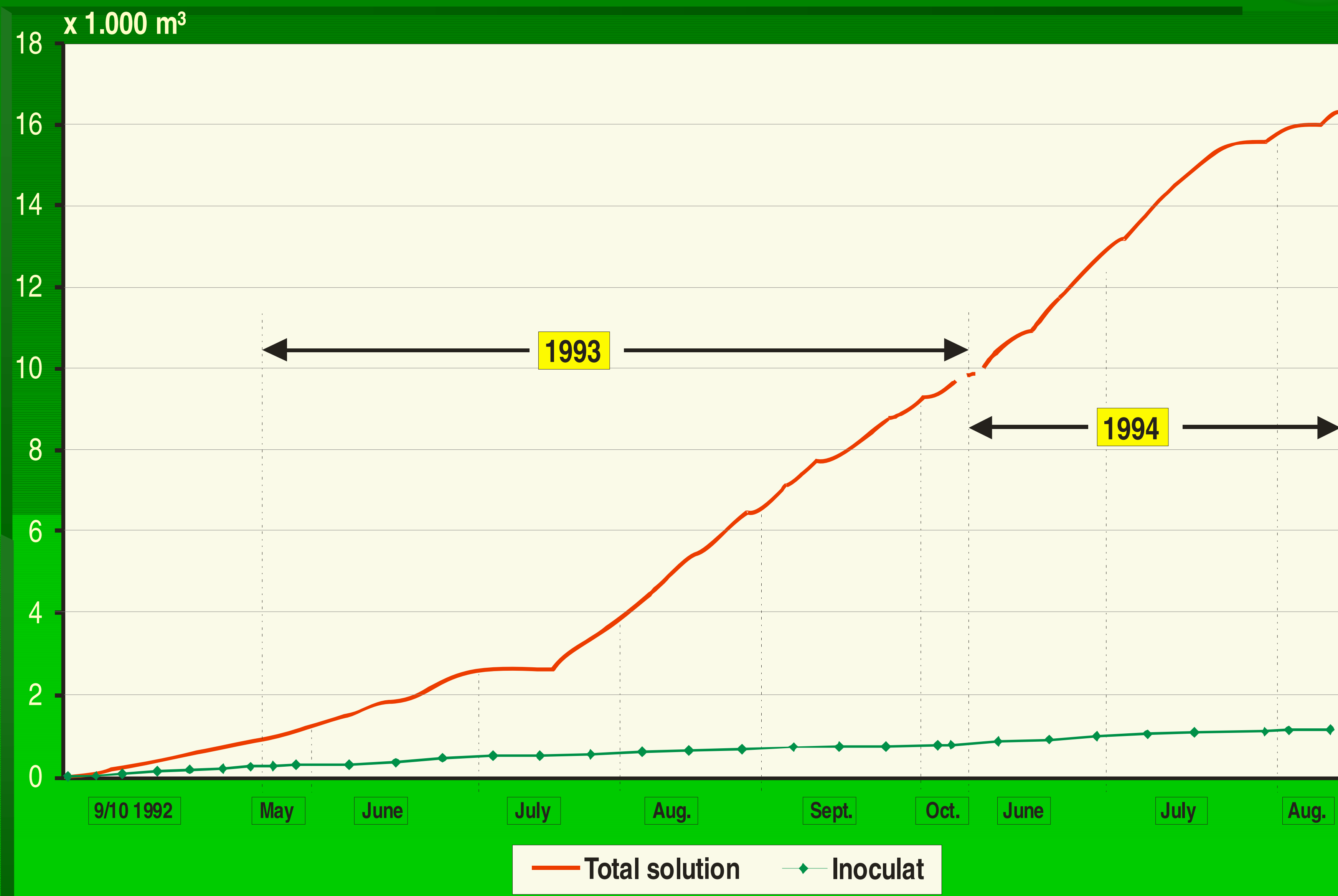
Biotechnical Pilot Station – "Romashkino"

Design of Fermentation and Injection Station

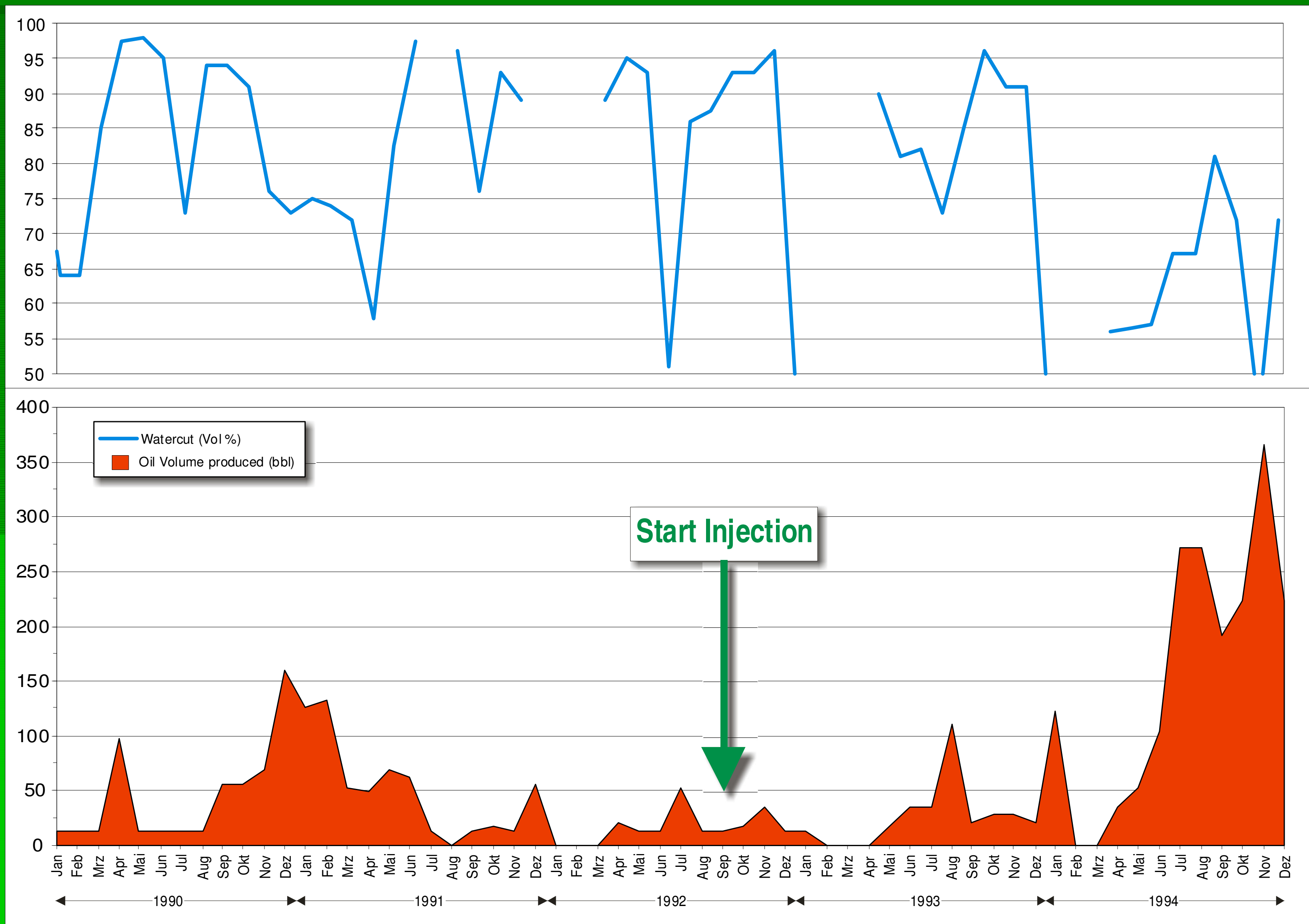
- Completely automatically operating pilot plant controlled by microbial activity.
- Production of bacterial culture: 10m³/day (total: 1,200m³)
- Injection rate (incl. molasses): 150-200 m³/day



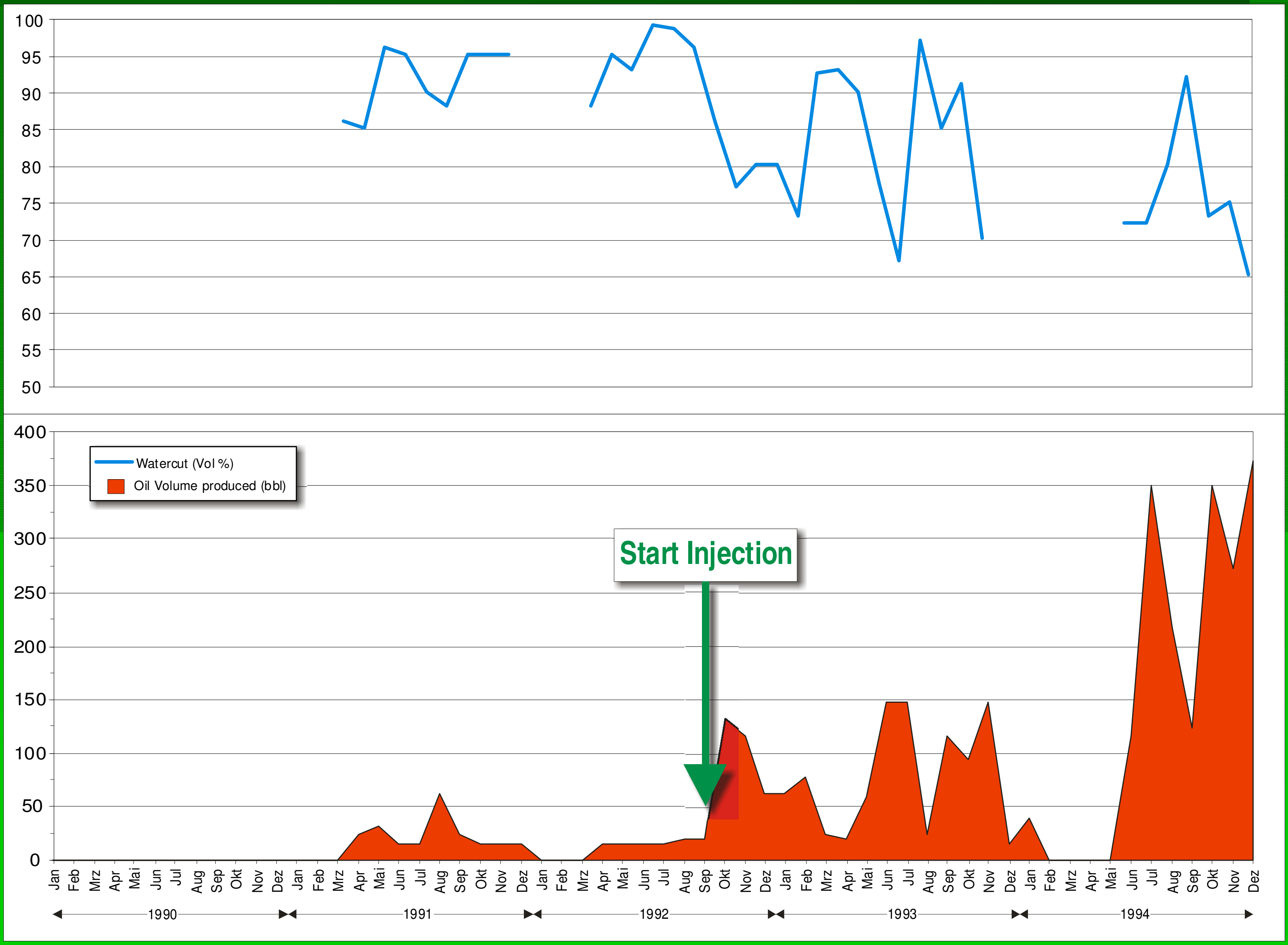
Cumulative Injection



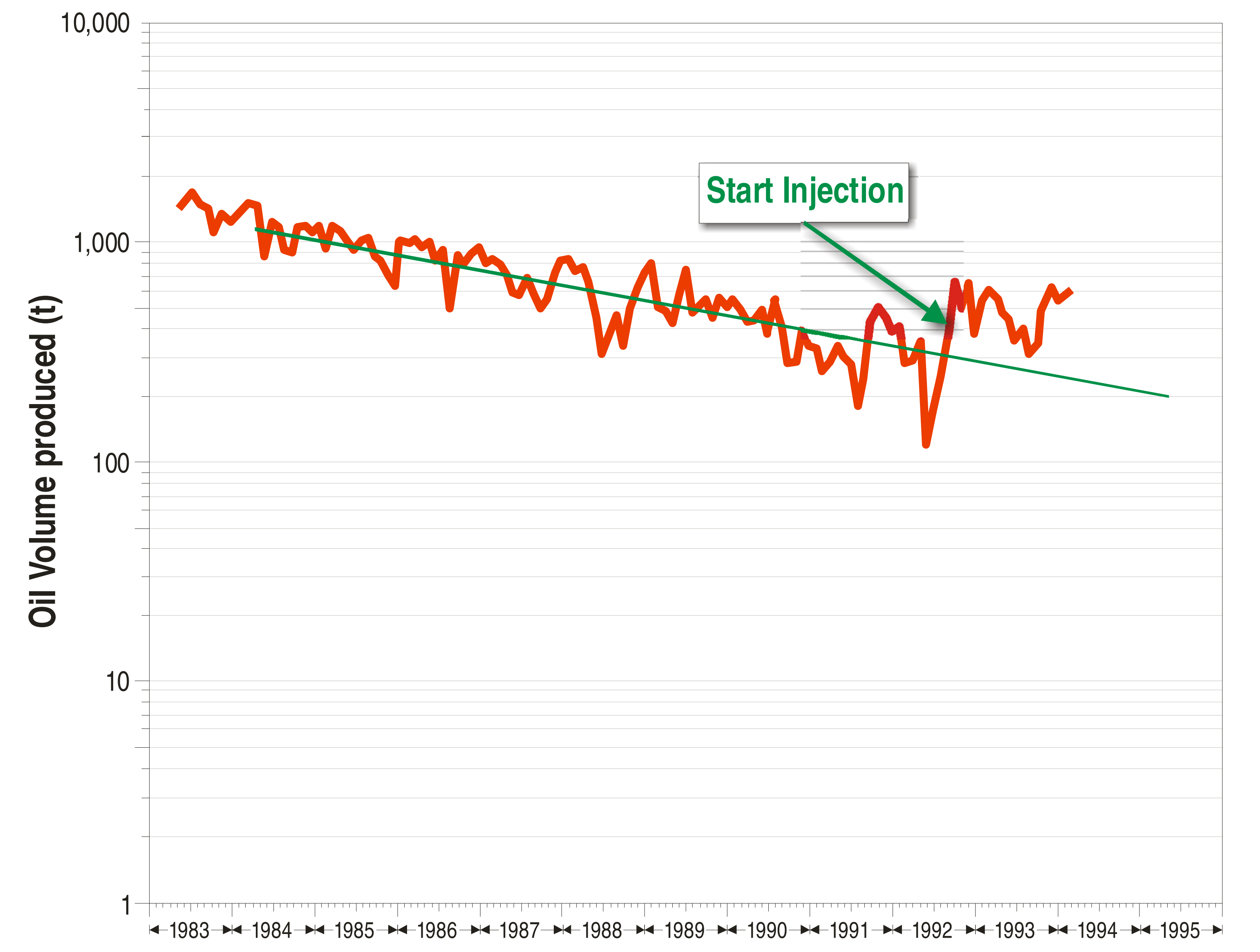
Oil Production at "Well 420"



Oil Production at "Well 432"



Total Produced Oil Volume – 24 Producers



Conclusion

- Intensive microbial insitu production of CO_2, H_2, organic acids, alcohols and surfactants have been verified under field conditions.
- Resulted of a decrease of water content by an average of 80 – 60% the oil content doubled.
- Lowering of oil viscosity, water content and an increase of gas/oil ratio leaded to an increase of daily production rate by about 50%.

The oil production increased to 250%.

Additional Costs for MEOR: ~3,5 $/bbl

MEOR – Cash Flow chart