



Your specialist partner for  
*in situ* soil remediation

A unique solution to remediate low permeability soils

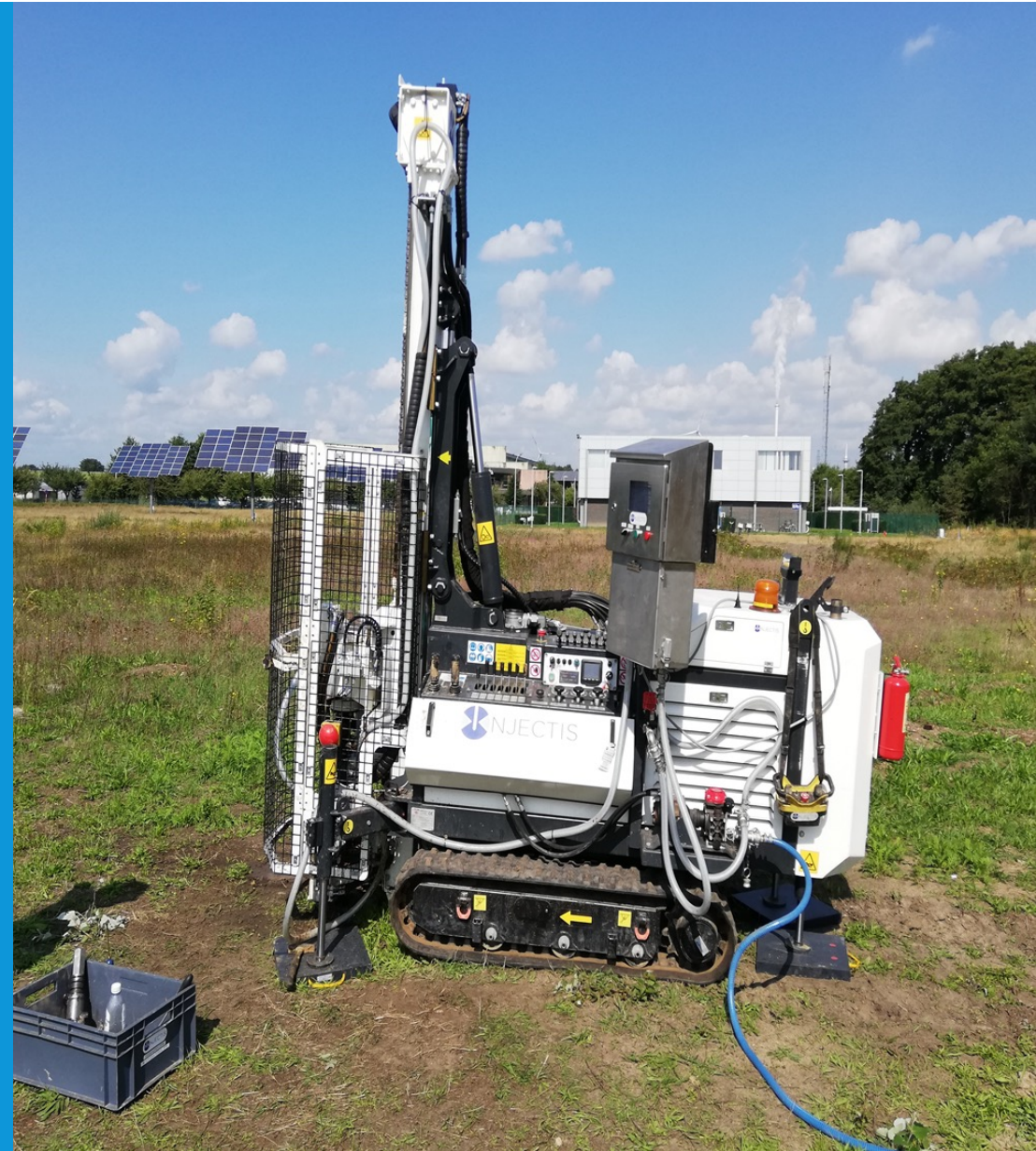


# Outline

- *In situ* soil remediation:  
Why?  
What?  
How?
- Direct Push : limitations in low permeability soil
- How to make it's work :  
SPIN<sup>®</sup> injection technology



Innovative solution for in situ soil remediation



*In situ soil remediation:  
Why?*



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# *In situ* soil remediation: Why ?

In situ



Treatment on site and in place

Why/when choosing for *in situ* soil remediation ?

- Low cost per m<sup>3</sup> soil/groundwater treated
- Large plumes with low/moderate concentrations (eg PFAS)
- Limited accessibility (eg buildings)
- Soil pollution at greater depths
- Low carbon footprint ↘ CO<sub>2</sub>(!!!)
- ...





*In situ soil remediation:*  
**What ?**



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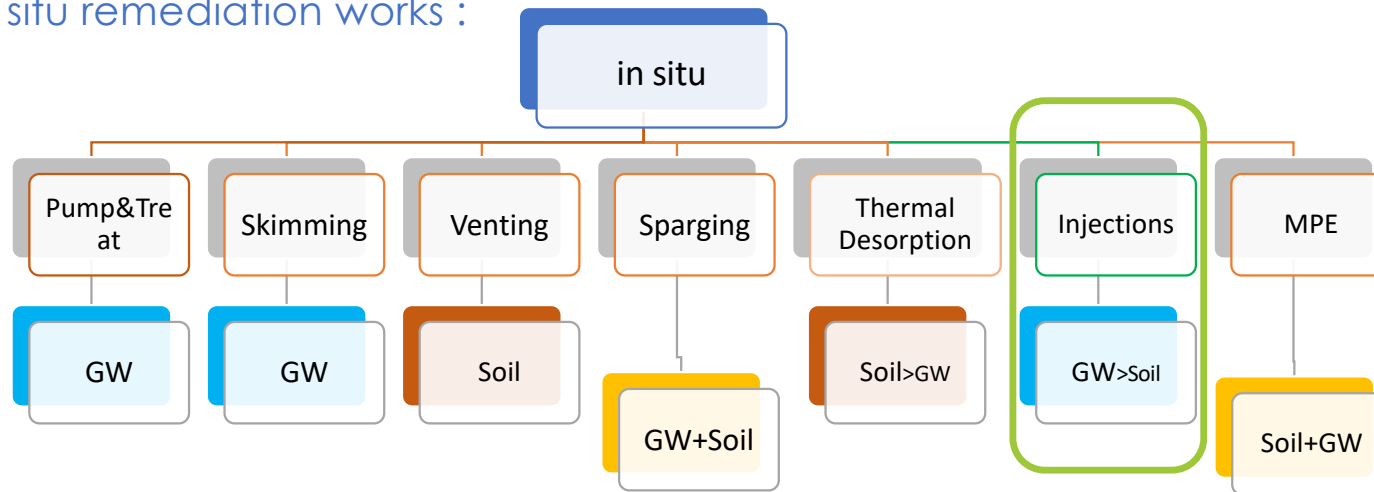
# In situ soil remediation: What ?

In situ



- Injections = in the saturated zone
  - Reactions take place in water
- Different injections system
  - Networks of wells, Direct Push, SPIN®

Main in situ remediation works :



Remediation enhanced by injection of reagents



*In situ soil remediation:*  
**How ?**

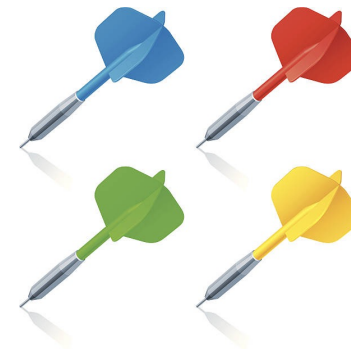
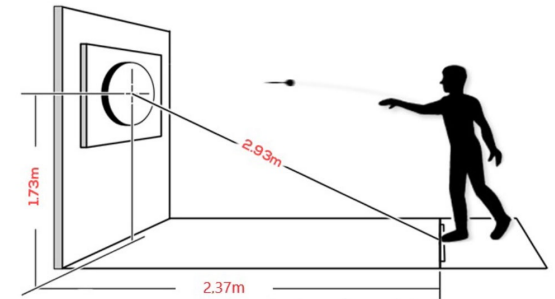
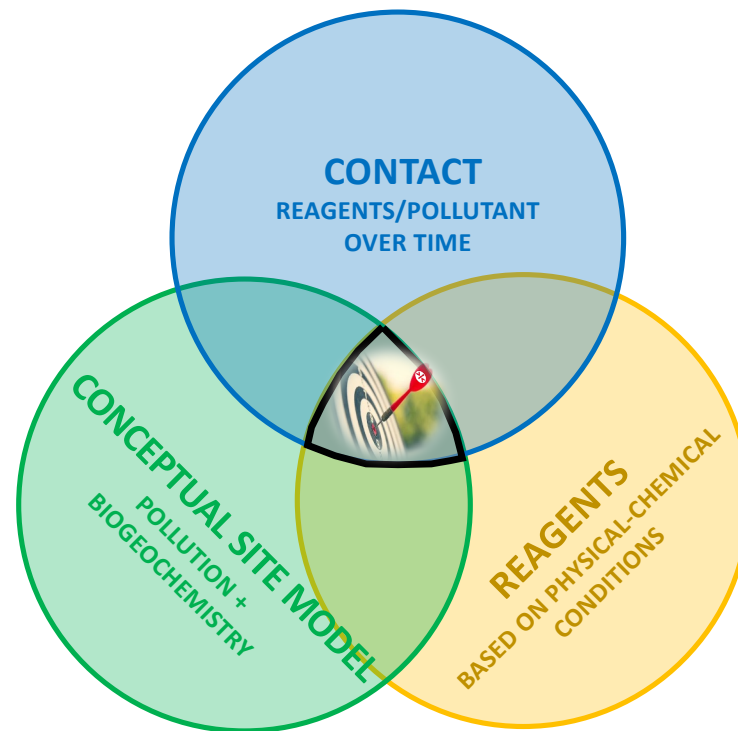


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# *In situ* soil remediation: How to make it work ?

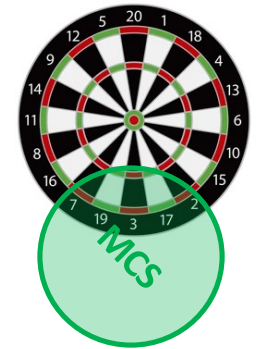
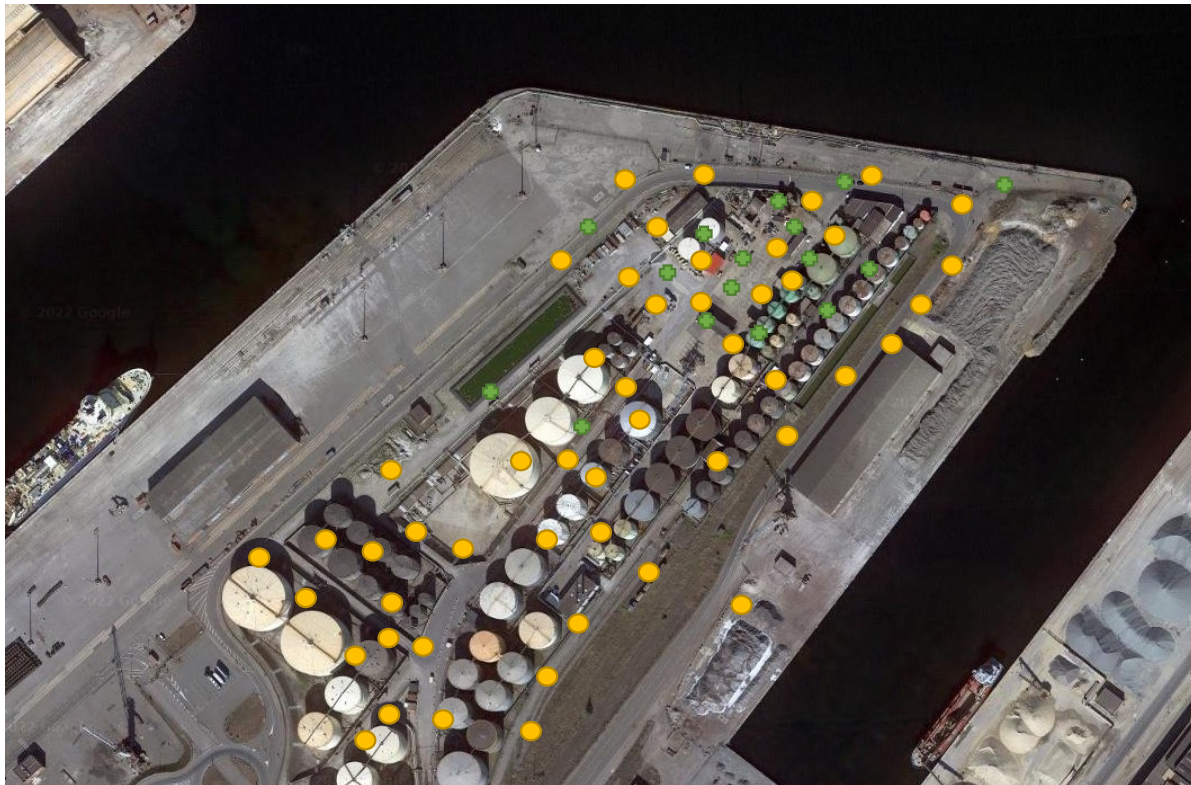


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# *In situ* soil remediation: How to make it work ?

## 1. A good characterization (CSM)



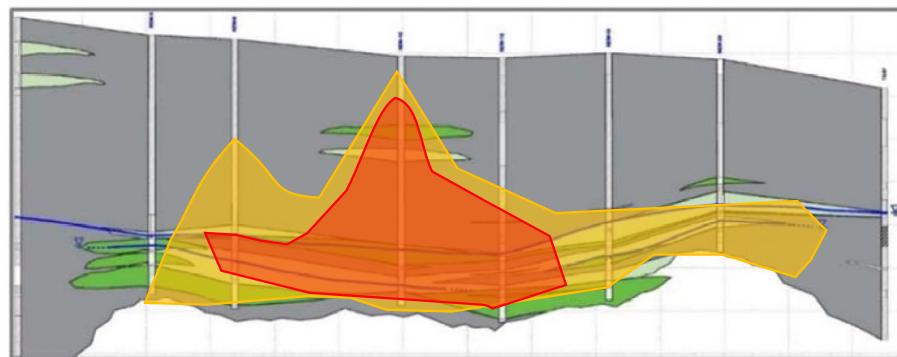
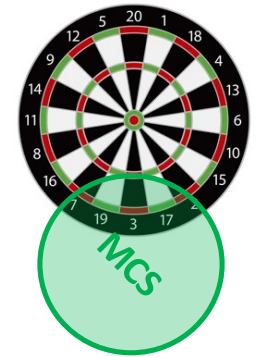
Good knowledge  
of the situation

**More** than the minimum  
criteria for the administration  
report

# In situ soil remediation: How ?

## 1. A good characterization (CSM)

- ✓ Source/origin of the pollution ?
- ✓ Presence of pure product (free phase) ?
- ✓ Pollutant(s) concentrations in soil/groundwater ?
- ✓ Physico-chemical parameters (upstream, plume and downgradient) ?
- ✓ Groundwater flow direction(s) ?
- ✓ Detailed hydrogeological data
- ✓ Natural degradation occurring?
- ✓ How far do we (need to) go ?



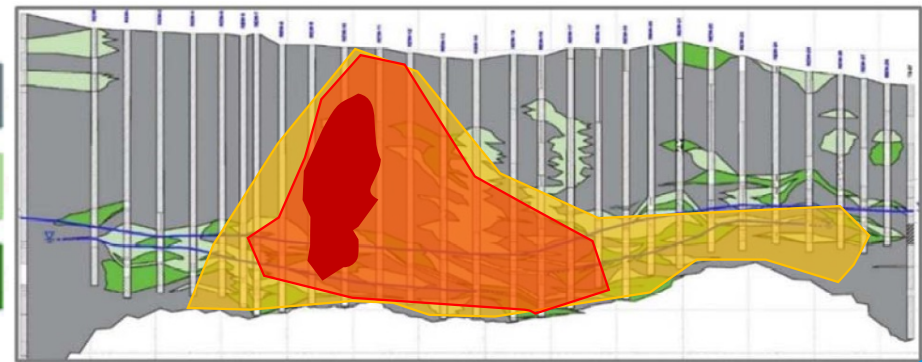
HETEROGENEITY !!

Ks

Low

High

Med



RESOLUTION of data !



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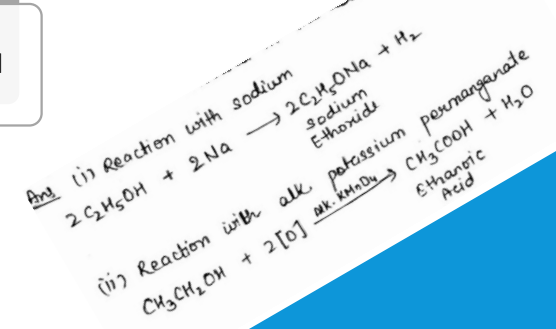
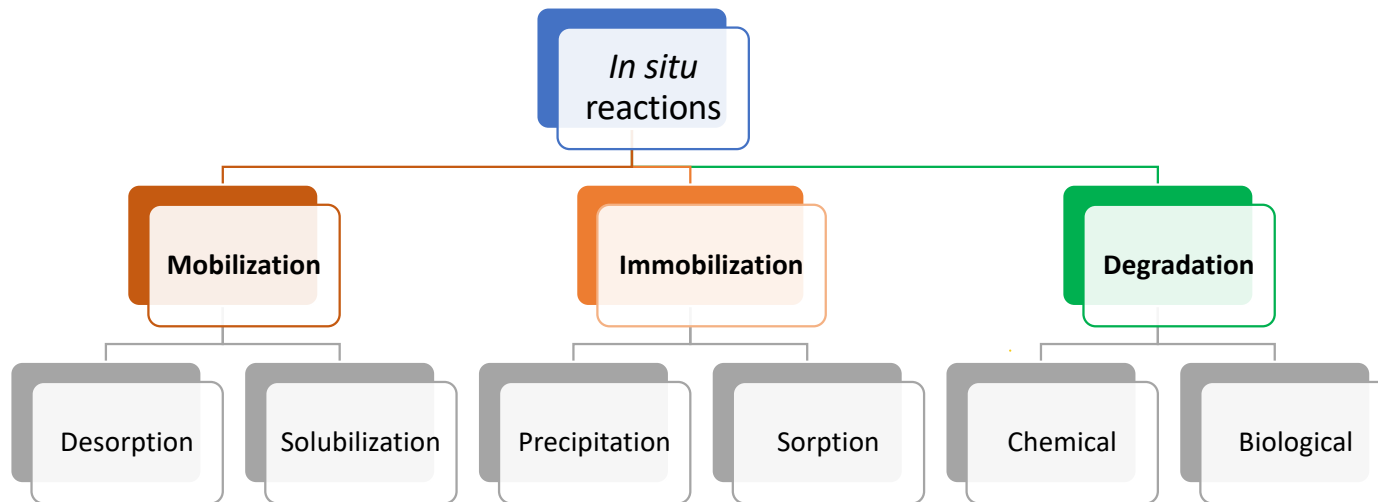
# In situ soil remediation: How ?

## 2. Selection of reaction and reagent



### Choice made based on:

- Properties of pollutant(s)
- Actual observed concentrations
- Final target concentrations
- Physico-chemical data
- Natural degradation potential
- (Hydro-)Geologie
- Presence of scavengers
- Longevity of reagents
- Mode of application



# In situ soil remediation: How ?

## 2. Selection of reaction and reagent



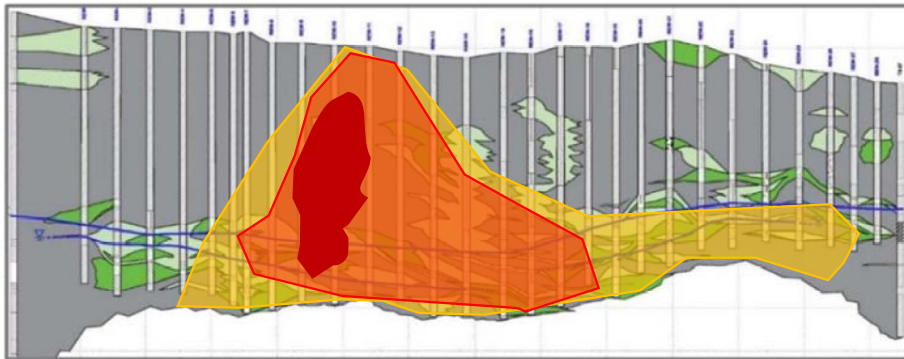
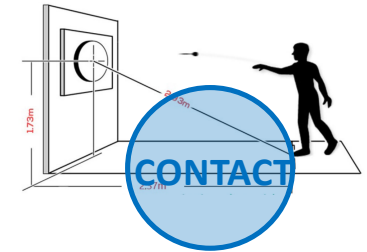
REACTION	Chemical		Biological		Physical	
	Oxidation	Reduction	Oxidation	Reduction	Immobilization/ Precipitation	Mobilization/ Desorption/ Solubilization
Injection of	Oxidant	Reductant	oxidant (e-acceptor)	reductant (e-donor)	Stabilisant/ precipitant	Surfactant (adjuvant)
Reagents	H <sub>2</sub> O <sub>2</sub> , Permanganate, Persulfate, O <sub>3</sub> ...	Zero Valent Iron (ZVI), hydrogen sulphide, CaSx, Dithionite	O <sub>2</sub> , H <sub>2</sub> O <sub>2</sub> , ORC®, nitrate, sulfate, calcium peroxide	Carbon sources: EVO, lactate, EHC®, Brenntapplus, EOS	Cement, Activated carbon, calcium oxide, Fe- oxides, FeS, NaOH, CaSx, zeolites	Surfactant (surface active agents), Co-dissolvents
Contaminants remediated	TPH BTEX CVOC Dioxane	CVOC PCB Cr(VI) Pesticides	LMW-TPH BTEX CVOC (DCM, DCE, VC)	CVOC (dechlorination)	Inorganic compounds (Pb, As...)	HMW-TPH MTBE PAH Heavy Metals CVOC (DNAPL)



# *In situ* soil remediation: How ?

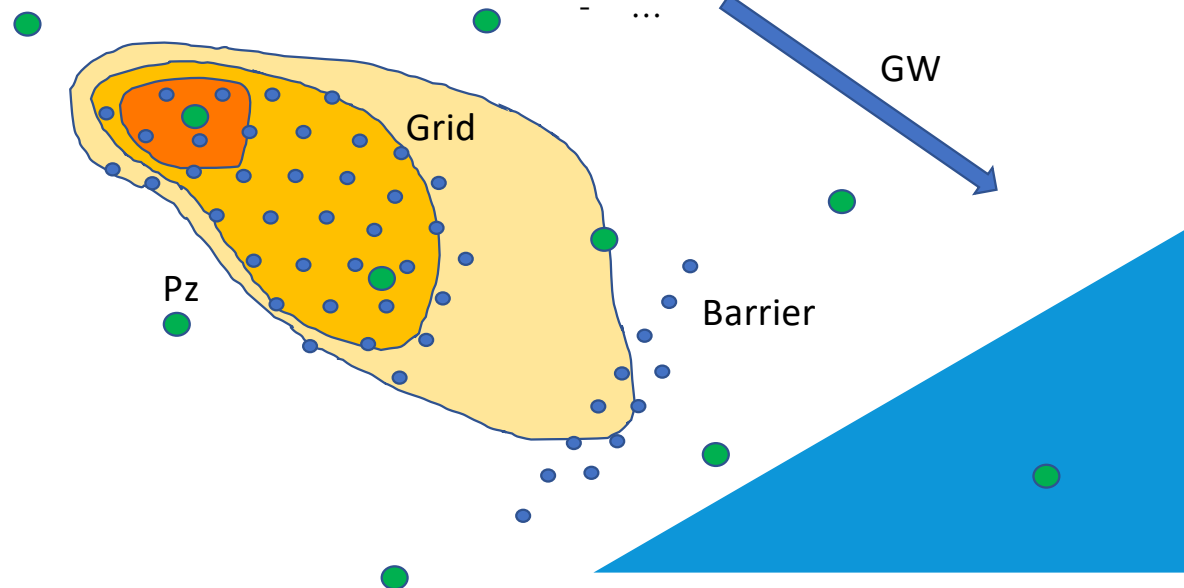
## 3. Contact between pollution and reagent

### Design of injection strategie



### Choice made based on:

- CSM (where)
- Actual observed concentrations
- Final target concentrations
- Groundwater flow direction(s)
- Geology
- Longevity of reagents
- ...



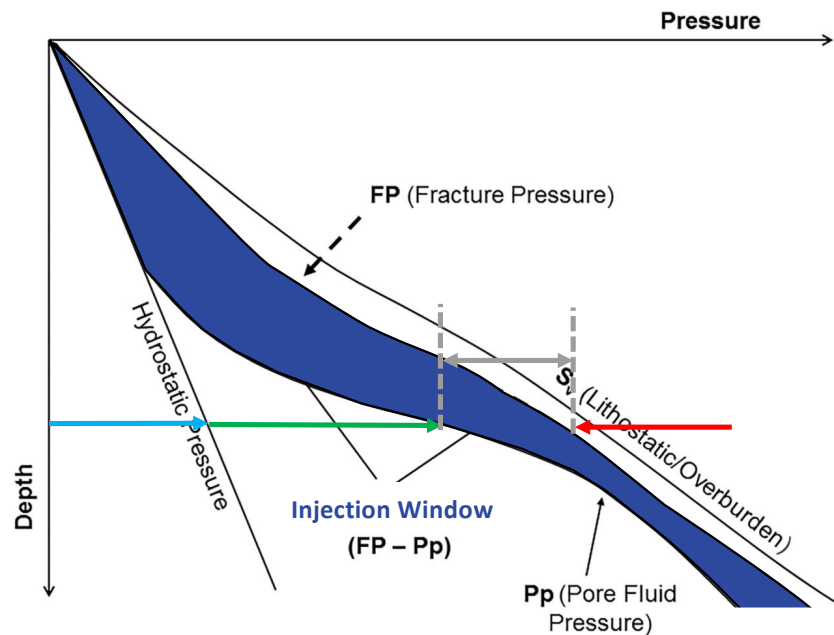
# In situ soil remediation: How ?

## 3. Contact between pollution and reagent

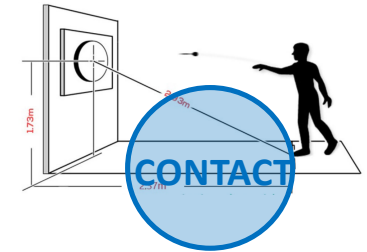
Selection of injection technique:

Pollutants present in natural soil porosity

→ Reagents to be injected in this porosity



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**Choice made based on:**

- Geology
- Reagents type
- ...

Injection pressure window depends on :

Soil depth

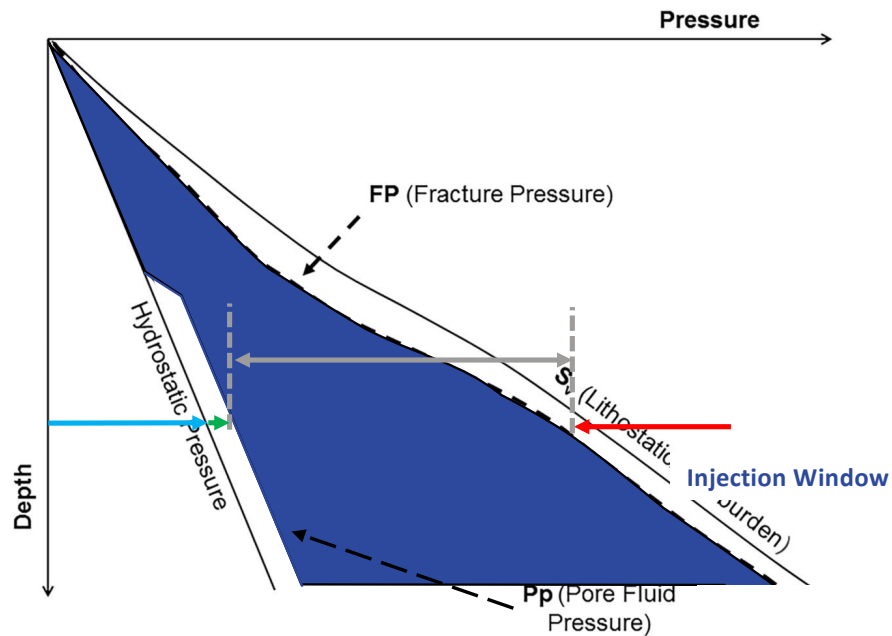
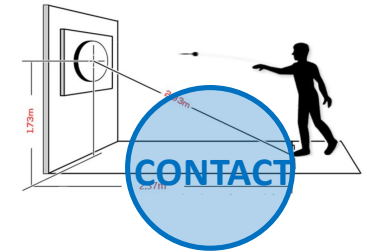
Groundwater level

Pore dimensions (soil texture)

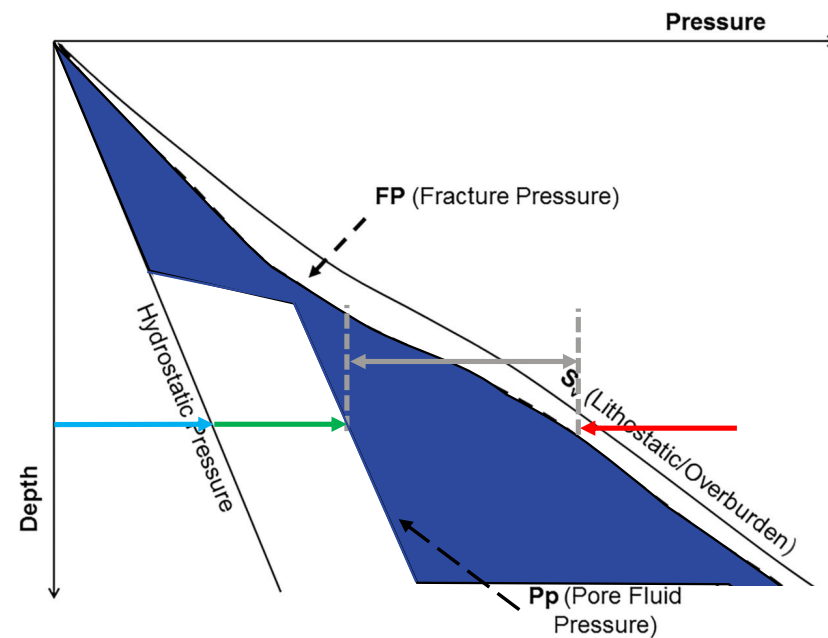


# In situ soil remediation: How ?

## 3. Contact between pollution and reagent



HOMOGENEOUS **SANDLY** aquifer



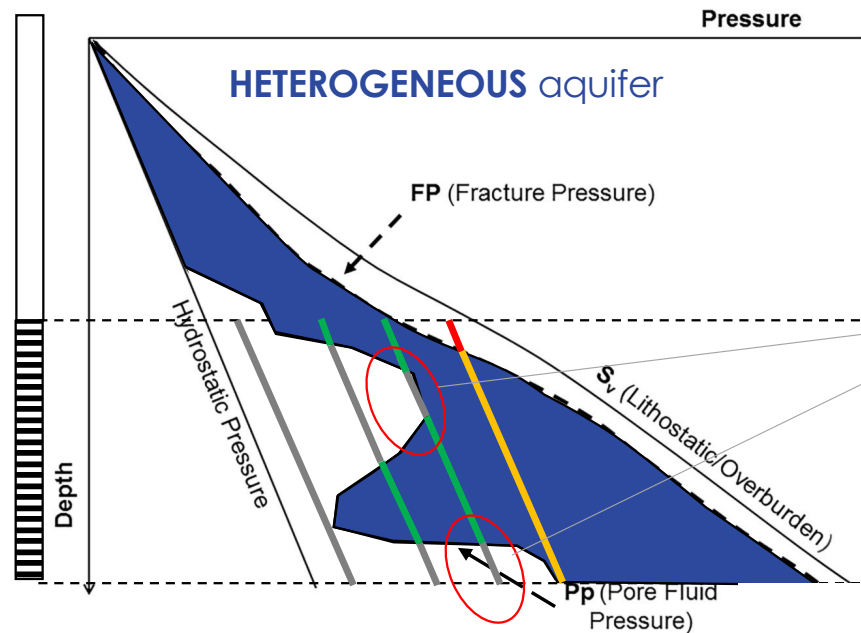
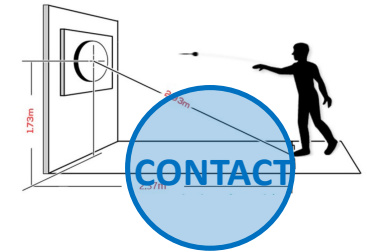
HOMOGENEOUS **CLAY** aquifer



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# In situ soil remediation: How ?

## 3. Contact between pollution and reagent



### Layers with low hydraulic conductivity

- Highest por pressure
- More susceptible to compaction
- Responsible to blow-out

### INJECTION PRESSURE

= CANNOT REMAIN CONSTANT AS A FUNCTION OF DEPTH

➔ NEED TO BE ADJUSTED/ADJUSTABLE



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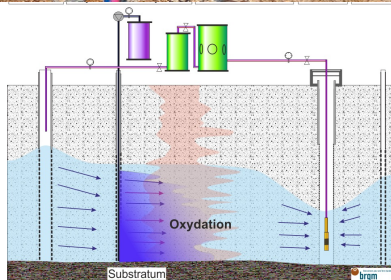


# In situ soil remediation: How ?

## 3. Contact between pollution and reagent

### 1. Injection wells

≈ 68%



+ recirculation



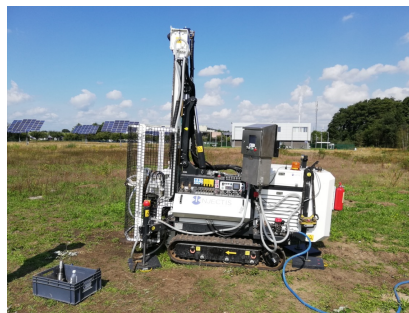
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### 2. Direct injections

≈ 30%



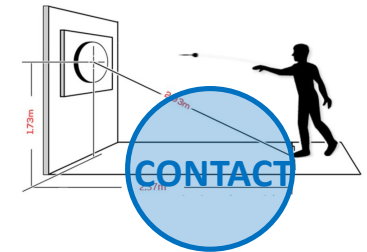
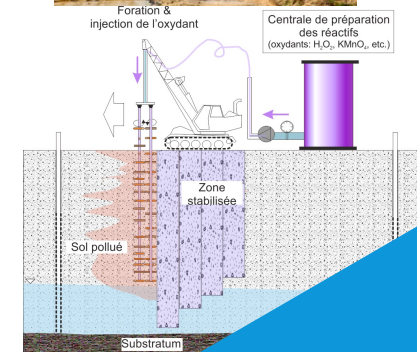
Direct Push



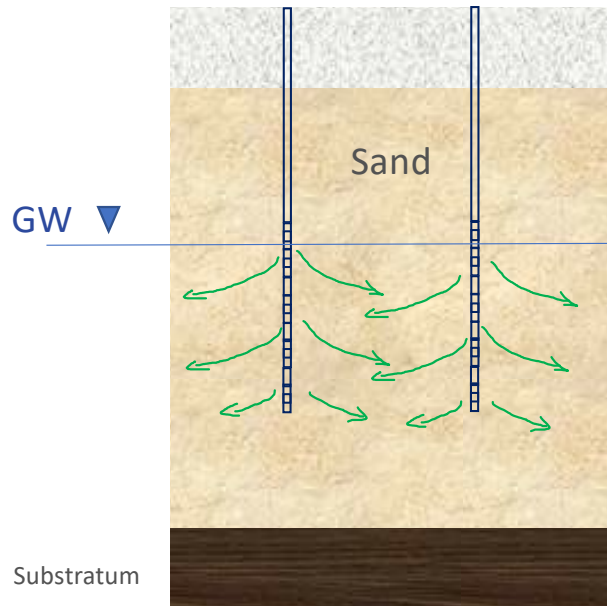
SPIN® Injectis

### 3. Soil mixing

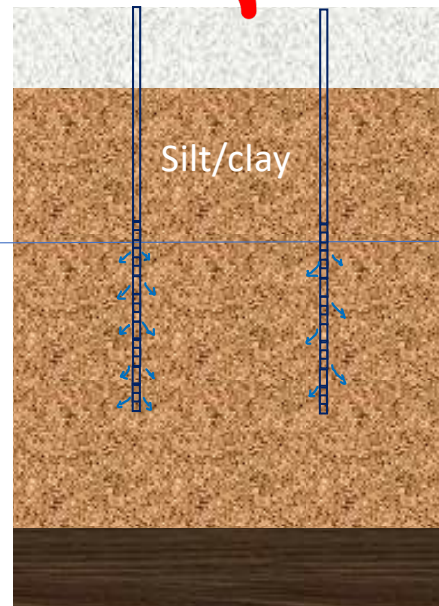
≈ 2%



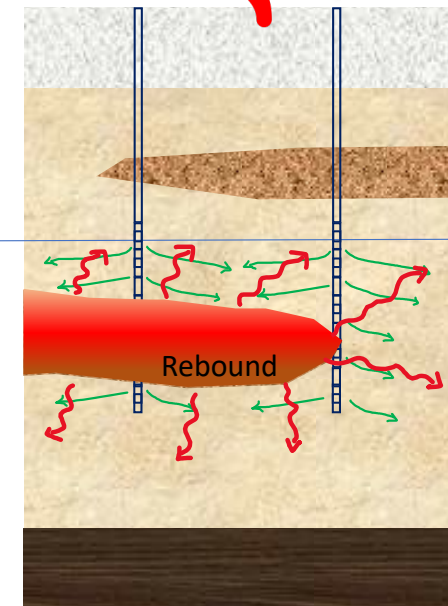
# Injection wells & recirculation systems



- ✓ In SANDY aquifer (homog.)
- ✓ High VOLUME injected
- ✓ Low COST



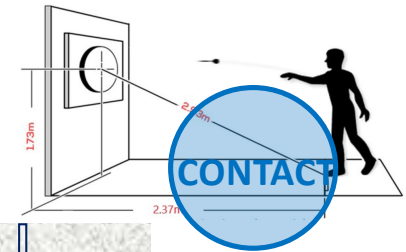
❌ In soil with LOW permeability



❌ In HETEROGENEOUS soil

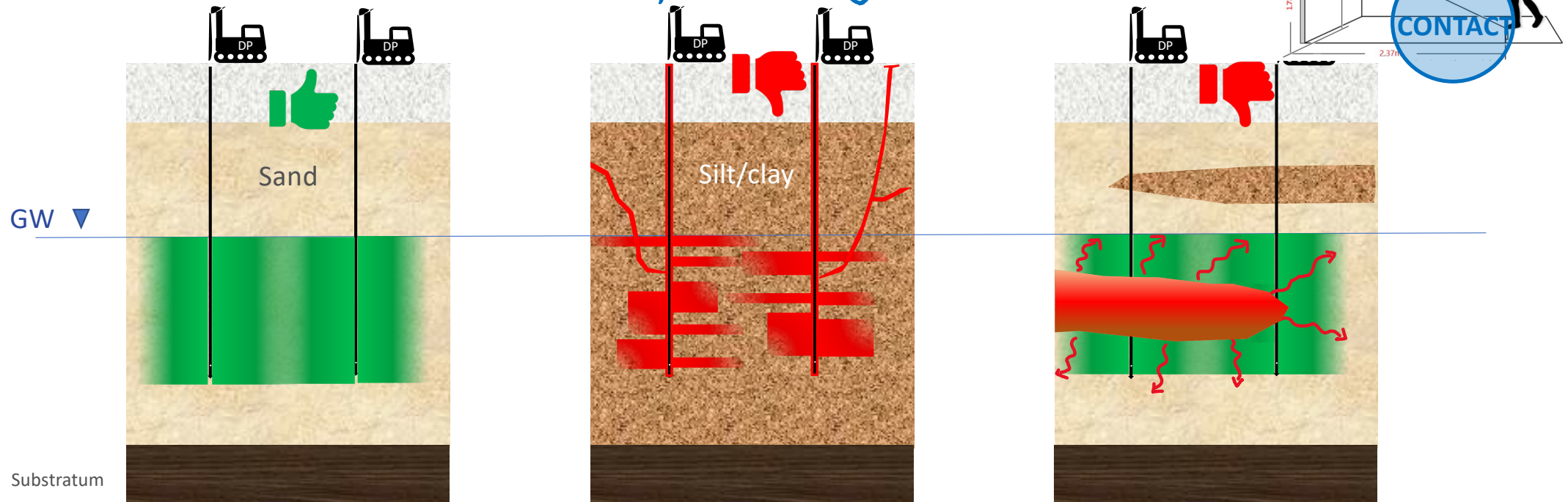
## Other common problems/limitations :

- ❌ Vertical heterogeneity (> 4m filter)
- ❌ Clogging (+ Material resistance > oxidant)
- ❌ Inundation risk
- ❌ Permanent installation with cost of exploitation
- ❌ Particles and emulsions not possible



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# Conventional direct-push injection



GW ▼

Substratum

- ✓ In SANDY aquifer (homog.)
- ✓ Depth Adapted injection
- ✓ Relatively low COST

- ✗ In soil with LOW permeability
- ✗ High pressure required -> fractures
- ✗ Heterogeneous distribution

- ✗ In HETEROGENEOUS soil

## Other advantages:

- ✓ Fast
- ✓ No permanent infrastructure

## Other limitations:

- ✗ Reflux of product after withdrawal
- ✗ Blow-out of product along the rods
- ✗ Fracturing > preferential flow paths

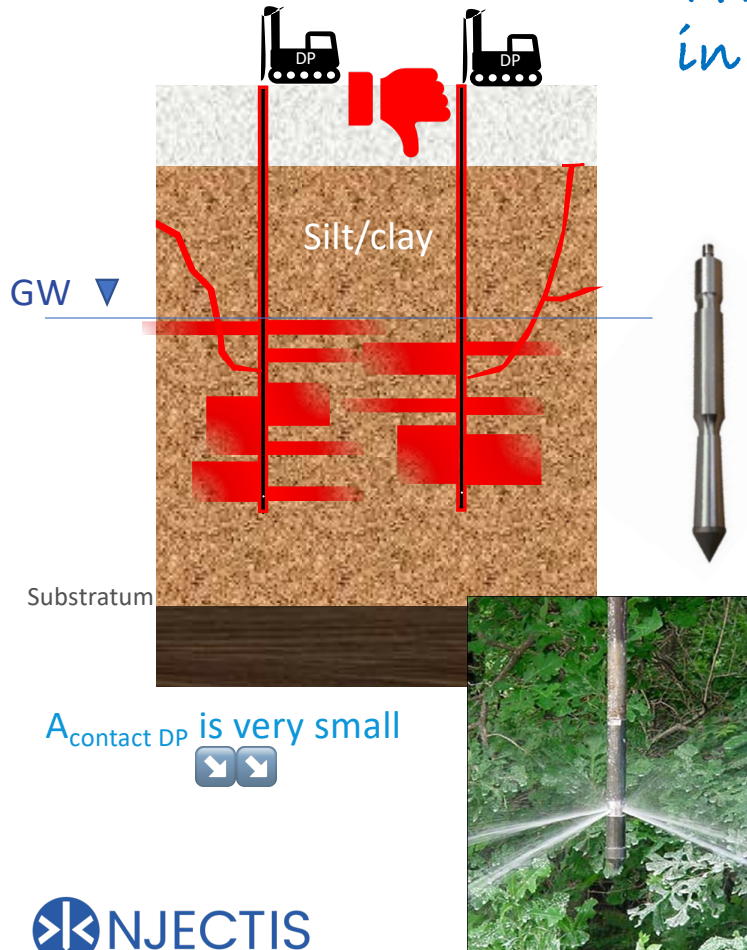


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# Conventional Direct Push:

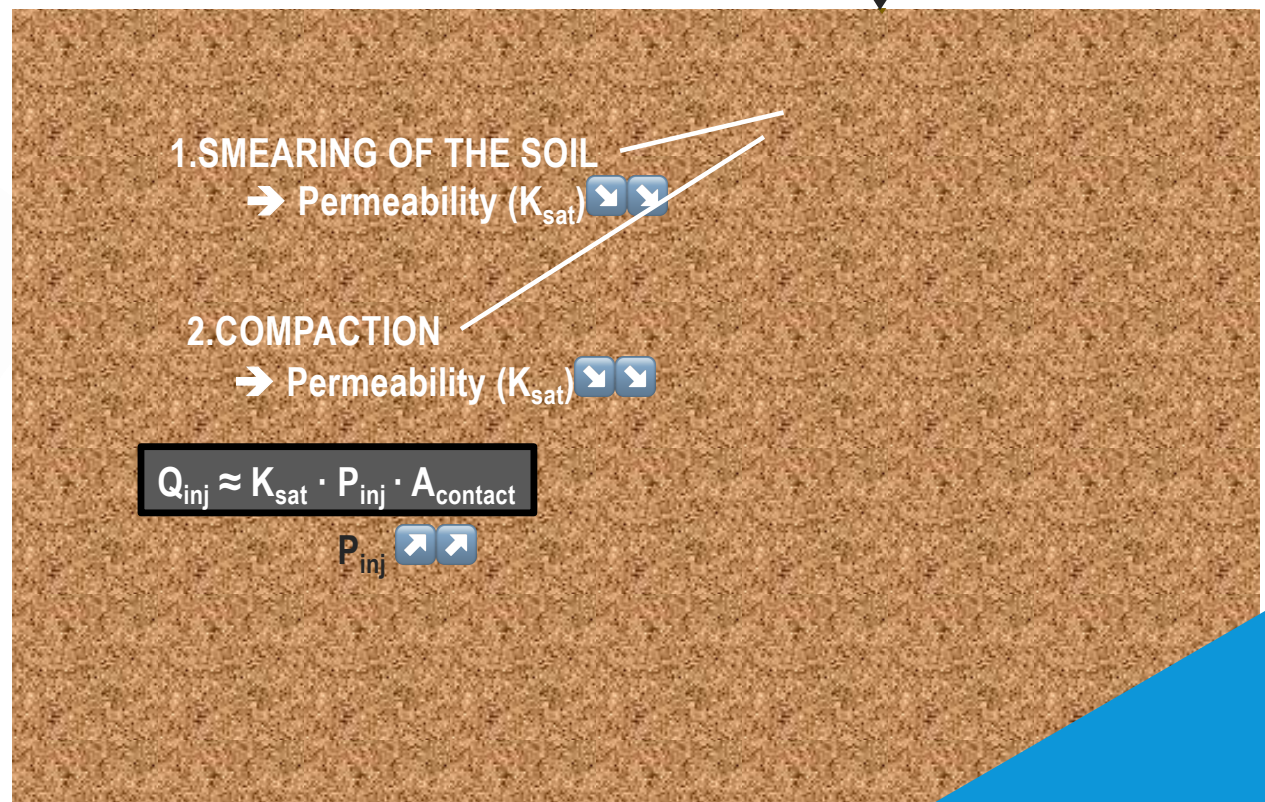
Why it doesn't work  
in low permeability soil?



$A_{\text{contact DP}}$  is very small



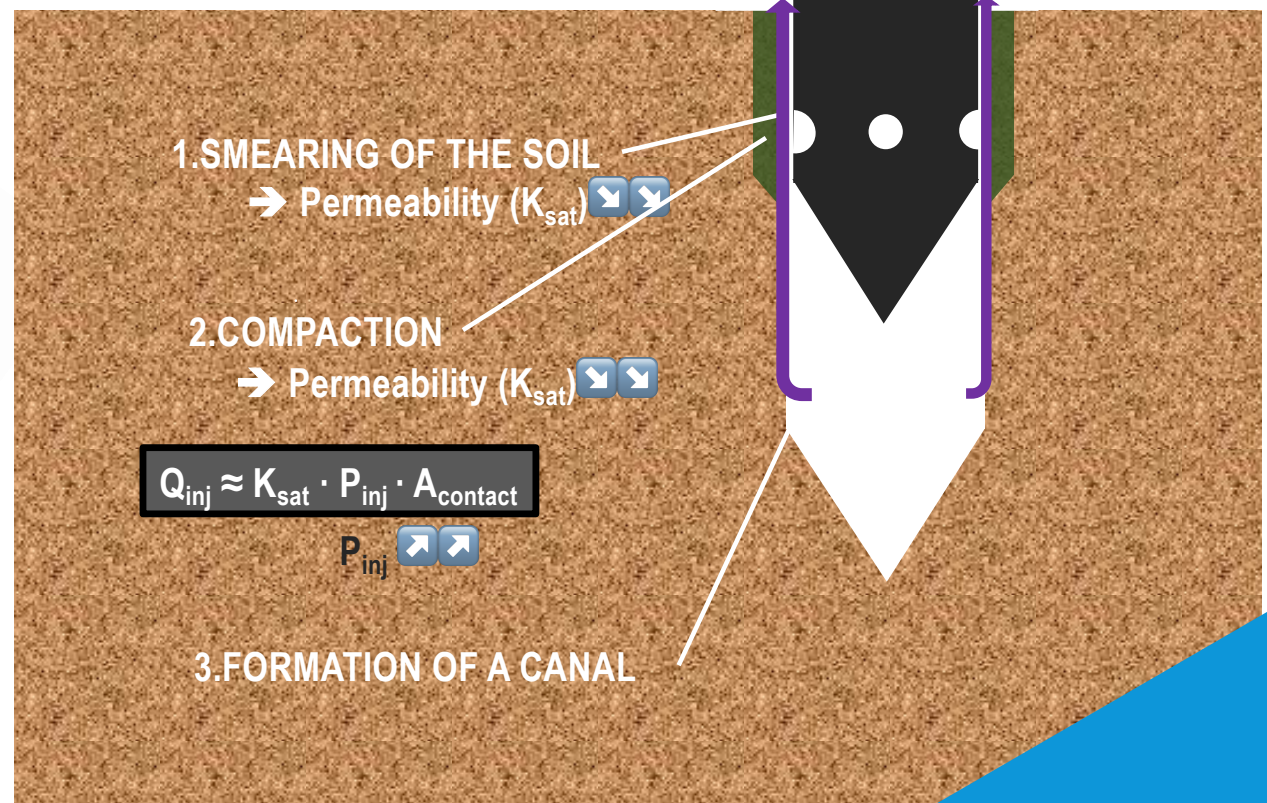
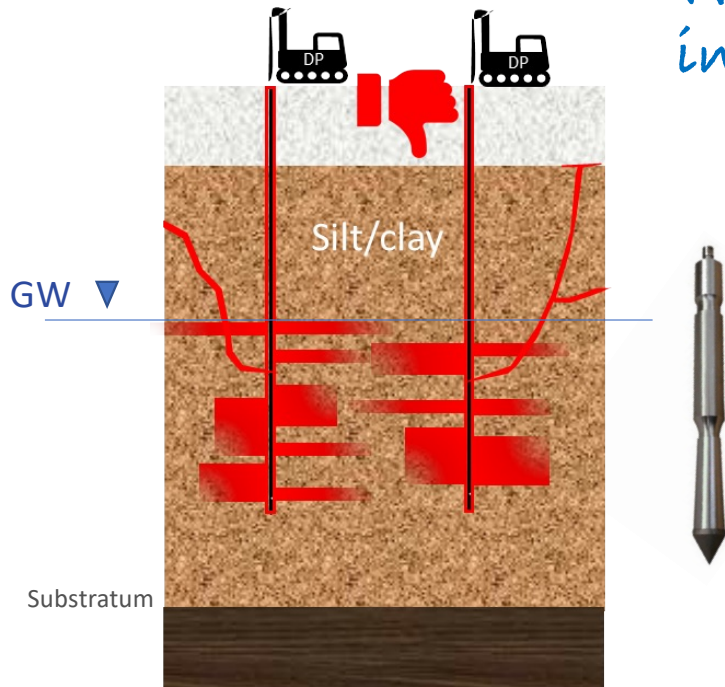
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$P_{\text{injection}} > P_{\text{critical,fracturation}}$  to maintain  $Q_{\text{inj}}$

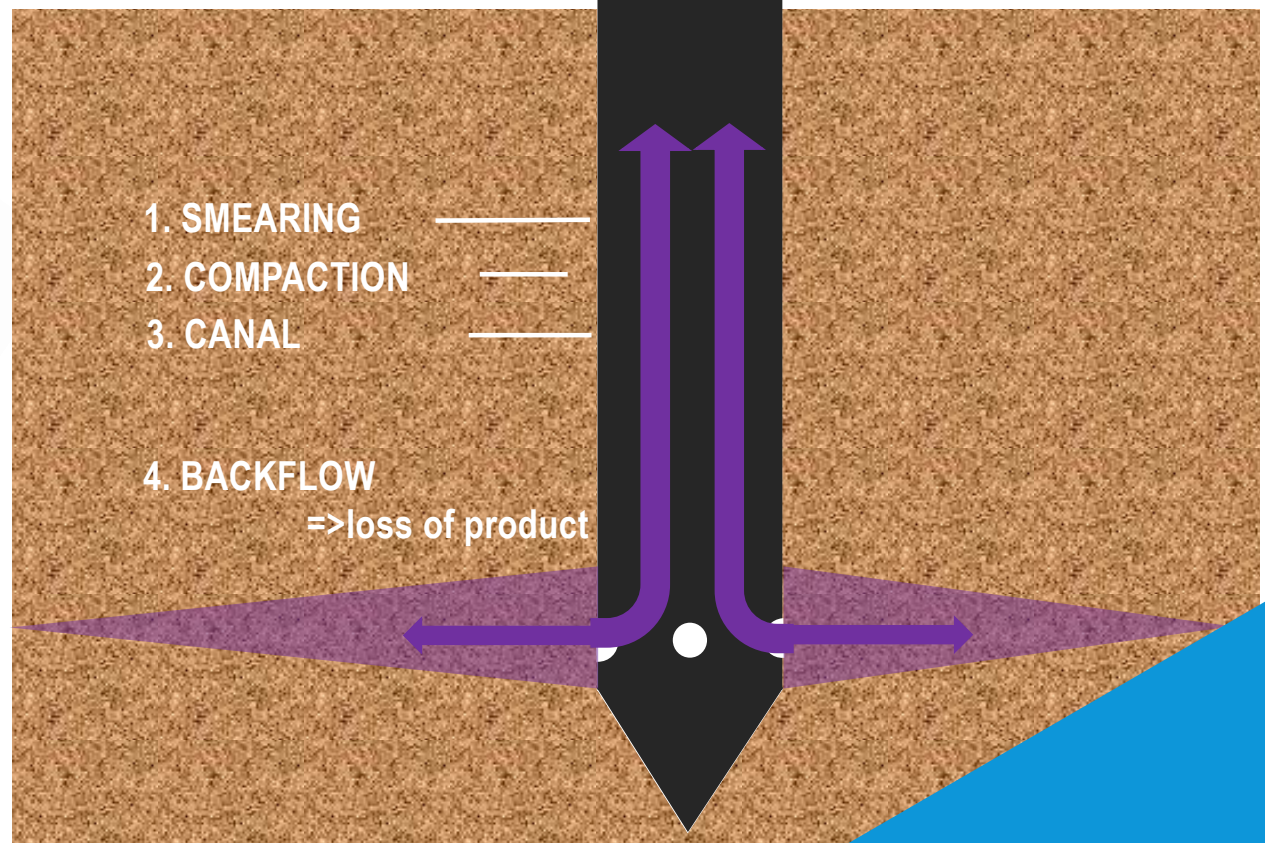
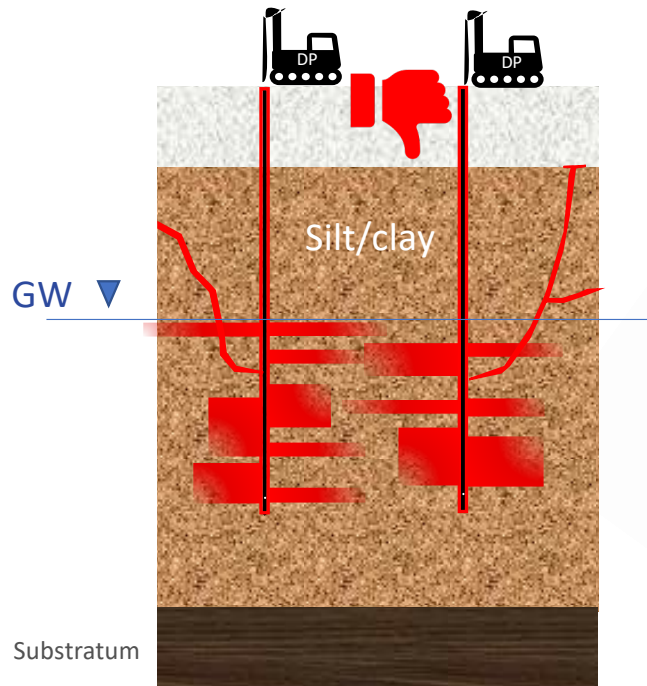
# Traditional Direct Push:

Why it doesn't work  
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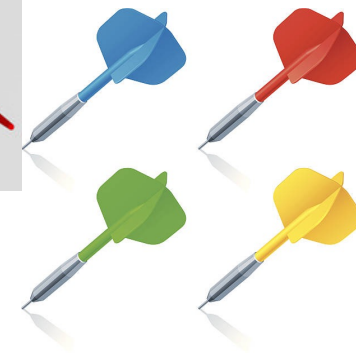
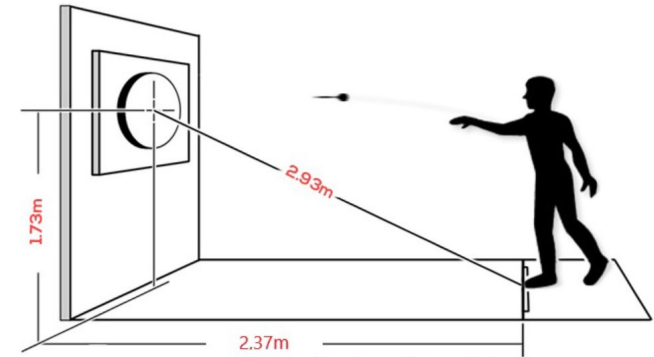
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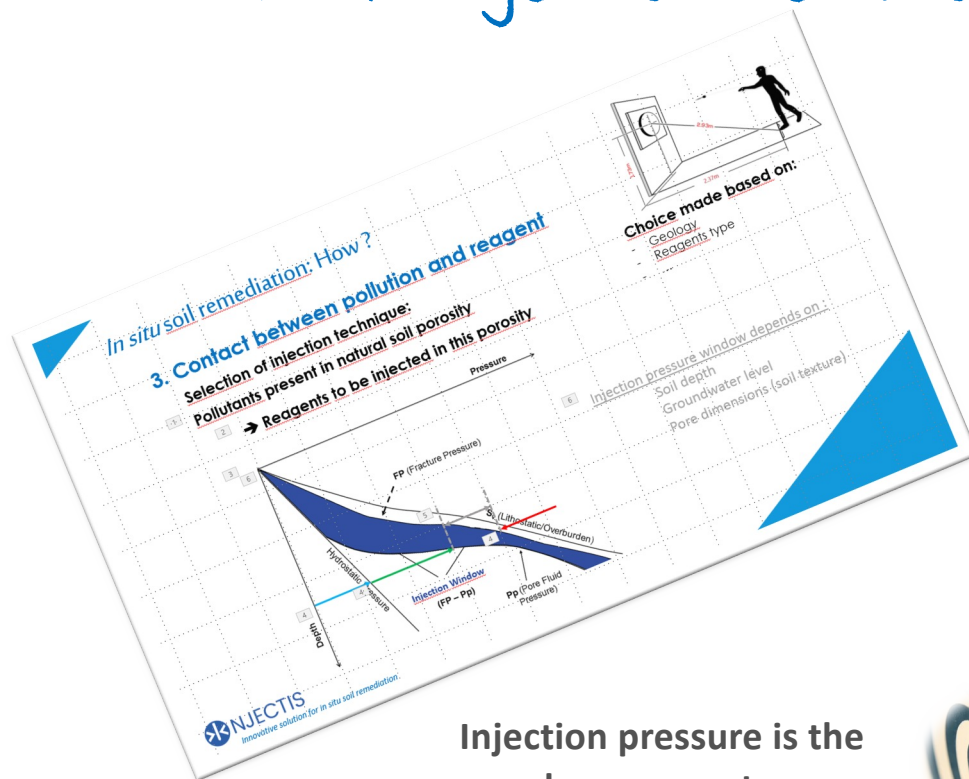


# *In situ soil remediation: How to make it work ?*

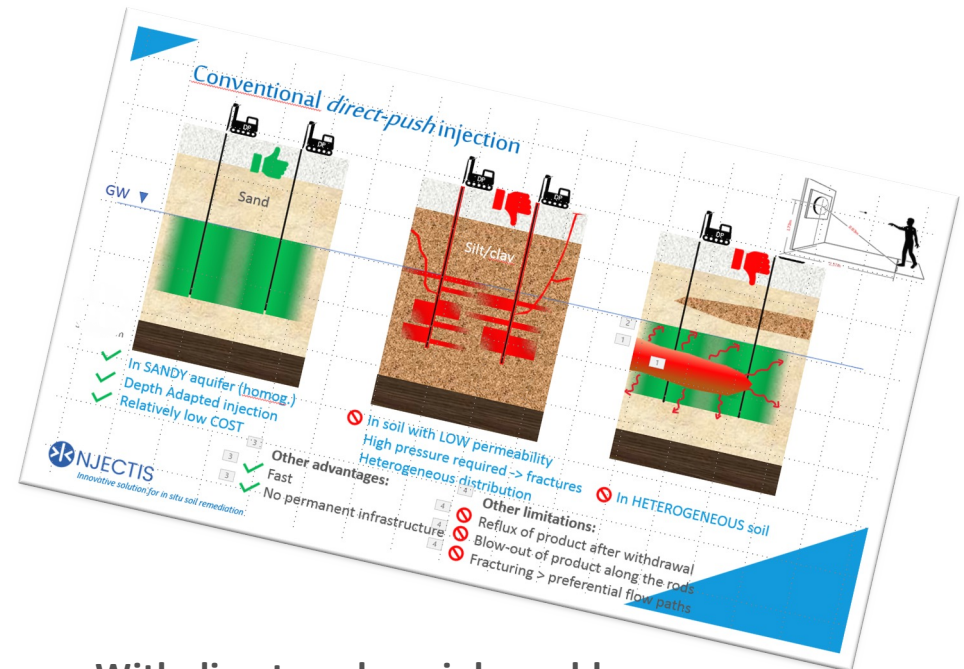


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# SPIN<sup>®</sup> injection technology: How to hit the bullseye?



Injection pressure is the key parameter



With direct-push mainly problems in heterogeneous and low permeability aquifers



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*SPIN<sup>®</sup> injection technology:  
How to hit the bullseye?*



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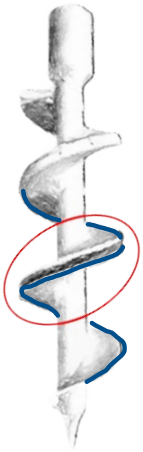




# SPIN<sup>®</sup> injection technology: How to hit the bullseye?



# SPIN<sup>®</sup> injection technology: *How to hit the bullseye?*

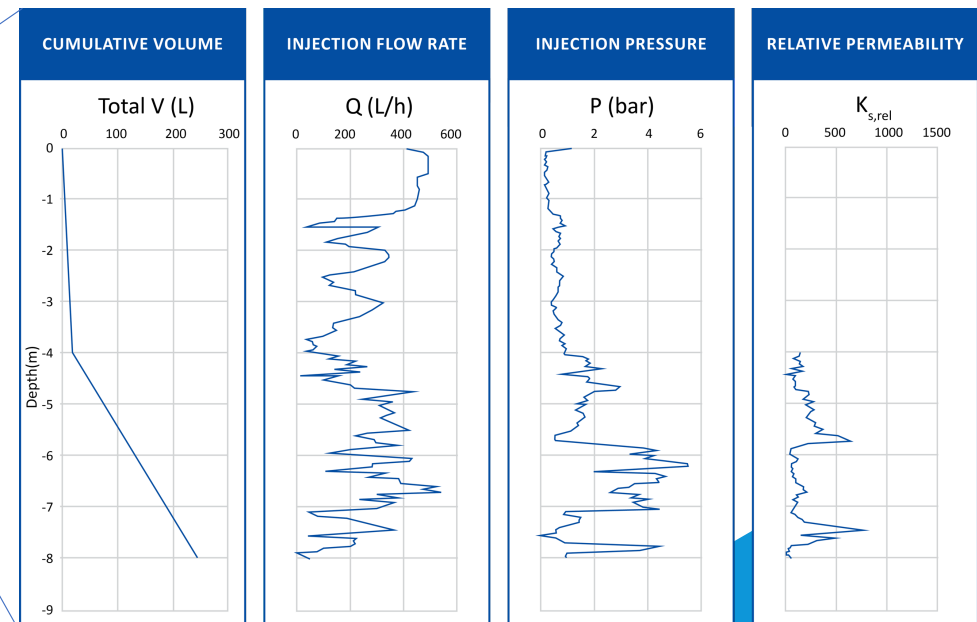
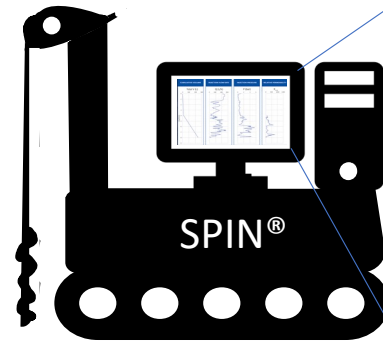


## 1. A new patented head

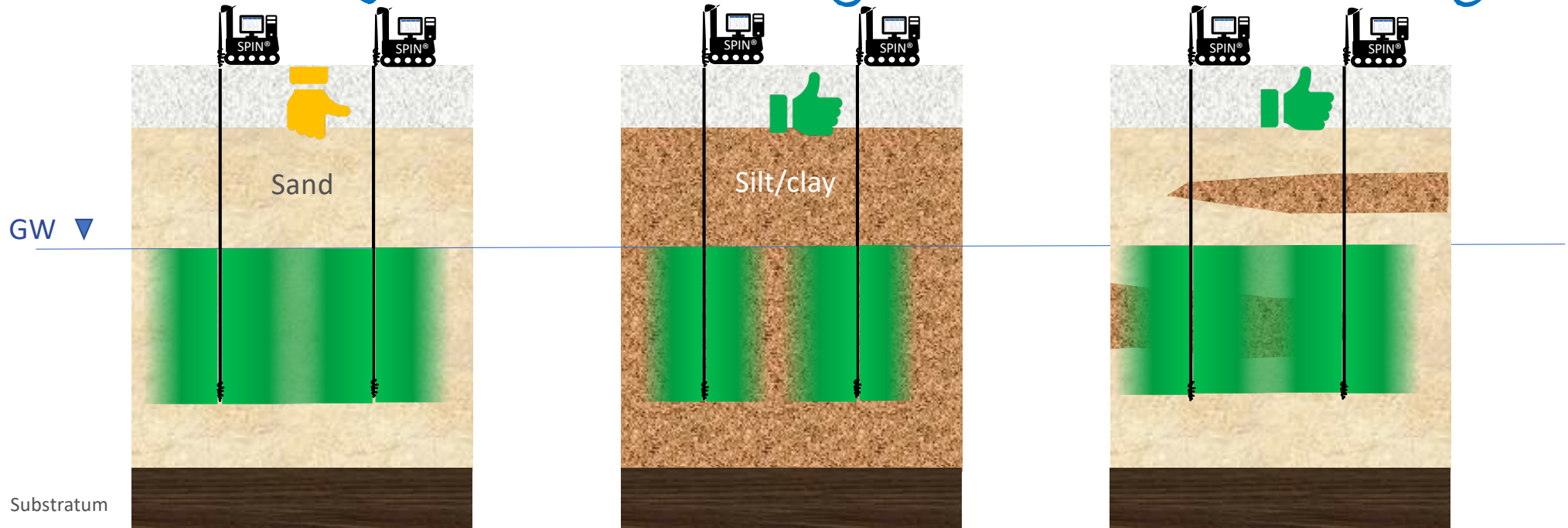
- ✓ Avoid compaction of the soil
- ✓ Opens the soil progressively
- ✓  $K_{sat}$  not altered
- ✓ Increased contact surface
- ✓ Allows working at low pressure
- ✓ Close the injection point (no backflow)

## 2. Coupled to a processor and pressure control system

- ✓ Can detect hydraulic conductivity in real time
- ✓ Can adapt the pressure cm/cm to the geology
- ✓ Guarantees a homogenous distribution



# SPIN® injection technology: How to hit the bullseye?



- ✓ In SANDY aquifer (homog.)
- ✓ Depth Adapted injection
- ✓ No significant advantage

- ✓ In soil with LOW permeability
- ✓ Low pressure > without Fracture
- ✓ Homogeneous distribution

- ✓ In HETEROGENEOUS soil
- ✓ Homogeneous distribution



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# NJECTIS

Thank you

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