

# RE-USE OF HYDROCARBON WELLS

**GERT-JAN HEERENS – TNO ENERGY**

**TNO** innovation  
for life

## SUMMARY

- Well sealing for CCS is an important element of the sealing “formation system”.
- Reuse of oil & gas wells from depleted reservoirs is studied to be used for CCS and gas storage.
- Restoring the formation sealing to ensure long term reliable sealing for plug and abandonment for oil and gas wells is has been explored.
- Feasibility studies and tests show that restoring formation sealing in the well bore with ductile formations like salt, shale and clay may provide a viable solution.
- Research and pilot tests are done in a open JIP project to develop the knowledge to restore the formation sealing for well abandonment and CCS (12 partners). (Information at [www.TNO.nl](http://www.TNO.nl), gert-jan.Heerens@tno.nl)

# AGENDA

› INTRODUCTION

› REGIONAL CHALLENGES

› RE-USE FOR CO<sub>2</sub> STORAGE

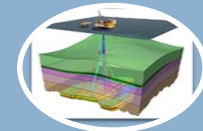
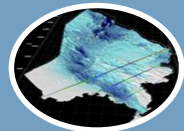
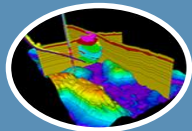
# NEW WELL CONSTRUCTIONS, RE-USE AND P&A

CCUS

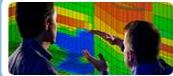
Geothermal

Oil & gas

En. Storage



Exploration



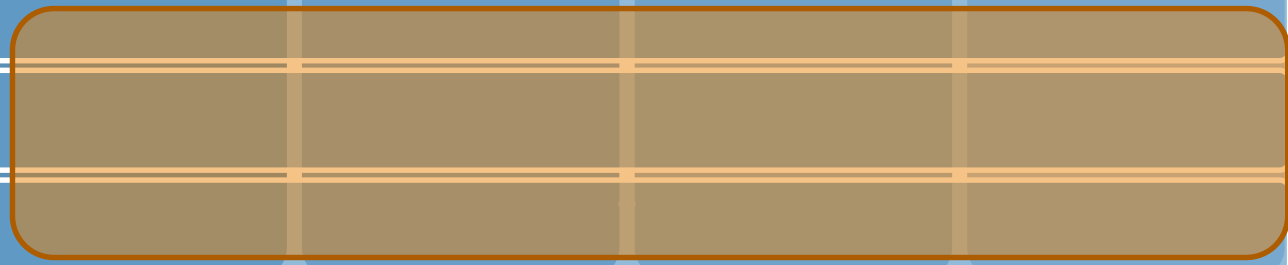
Production



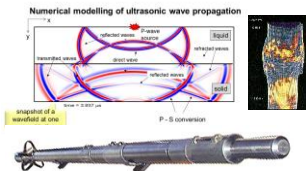
Infrastructure



Decom



## ULTRA SONIC



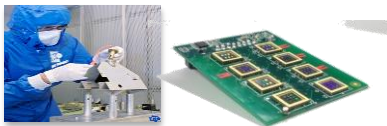
## MULTI PHASE FLOW DYNAMICS



## MATERIAL SCIENCE POLYMERS, CEMENT, CLAY MINERALS



## SENSOR/FIBER OPTIC



# WELL CONSTRUCTION

### TNO GEOMECHANICS

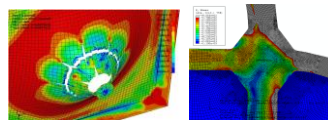
MINIMIZING RISKS AND OPTIMIZING RESERVOIR EXPLOITATION

<p>Field-scale Coupled Modelling</p>	<p>Induced Seismicity &amp; Seismic Hazard</p>	<p>Subsidence &amp; Surface Movement</p>
<p>Fault Sealing &amp; Stability</p>	<p>Shale Gas</p>	<p>Well Integrity</p>

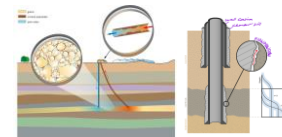
## PROBABILISTIC MODELLING



## STRUCTURAL STRENGTH



## GEO-CHEMISTRY



# DENSE POPULATED REGIONS HIGH SAFETY

## STANDARDS



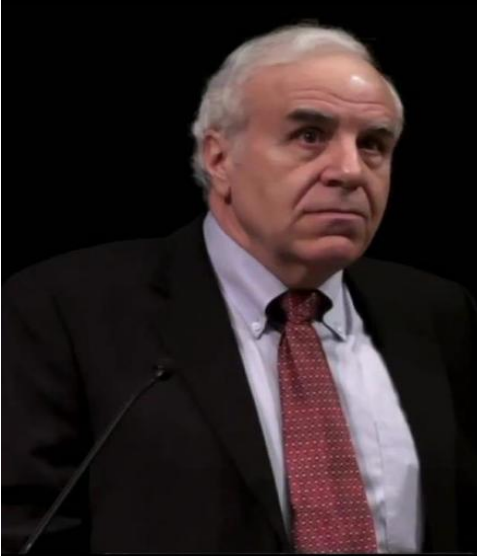
- › Oil wells in residential areas;
- › High safety standards



# CONSTRAINS DUE TO ENVIRONMENT



# LICENSE TO OPERATE; DEALING WITH UNKNOWNS



**6.2% of all well casings fail initially(\*)**, leading to methane migration.

60% fail over 20 years. They all fail over time.

These numbers are from the PA DEP. Why doesn't the industry fix this systemic problem?

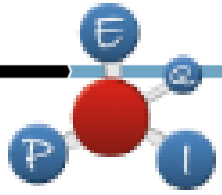
**BECAUSE THEY CAN'T!**

-- Dr. Anthony Ingraffea,  
Distinguished Professor of  
Engineering, Cornell University

\* Source: PA DEP. See: <http://youtu.be/7DK3fODCZ3w#t=30m46s>

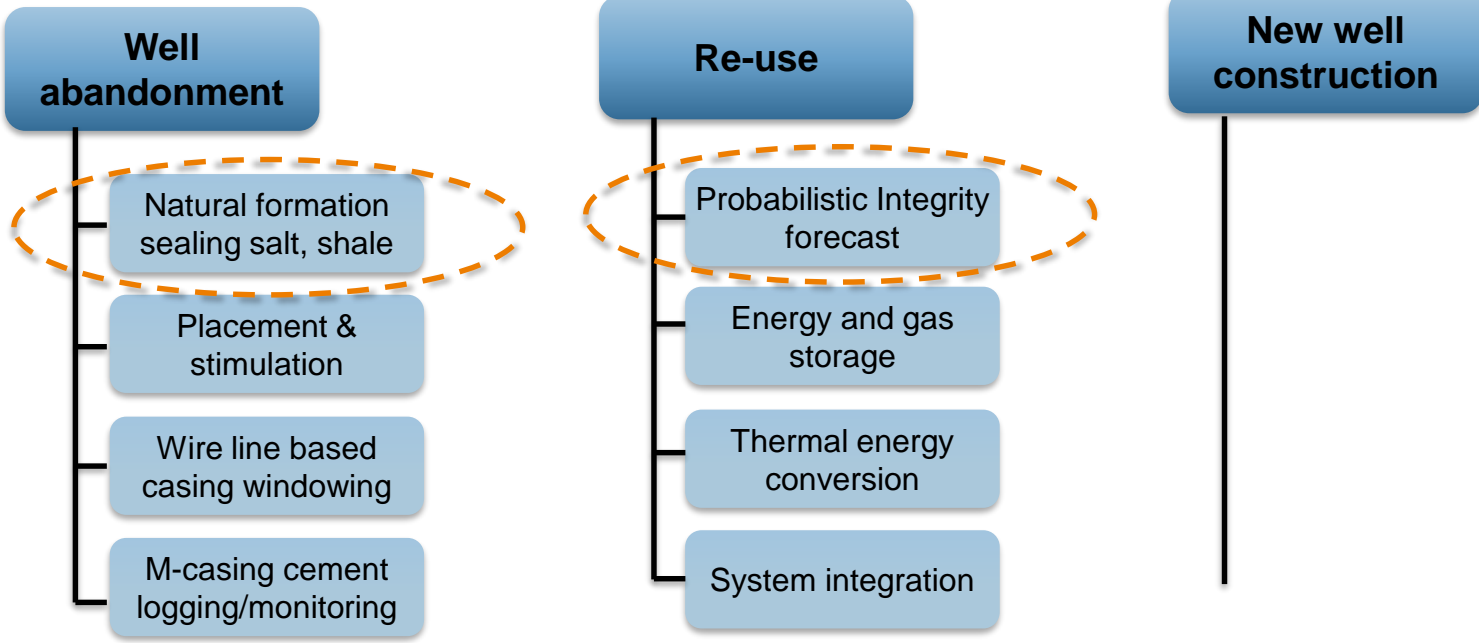
Ingraffea has been a [principal investigator on research and development projects](#) ranging from the National Science Foundation, National Aeronautics and Space Administration (NASA) through Schlumberger, Gas Research Institute, Sandia National Laboratories, Association of Iron and Steel Engineers, General Dynamics, Boeing and Northrop Grumman Aerospace.





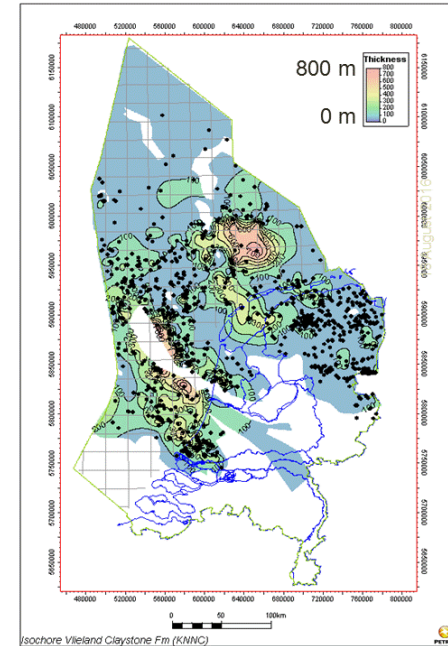
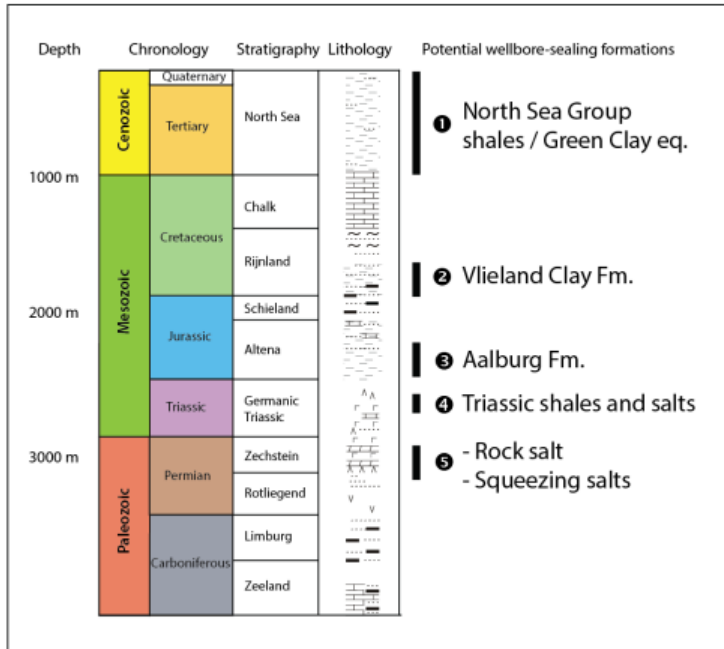
# OPEN JIP CONSORTIUM

## WELL INTEGRITY, RE-USE AND P&A

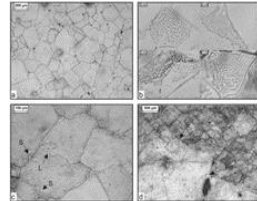
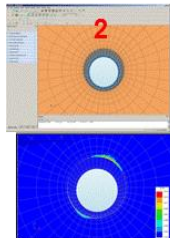
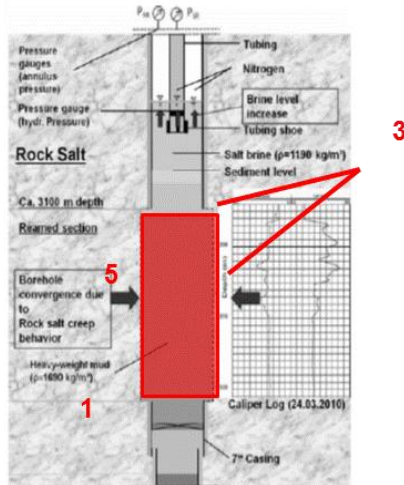


Connect with regulator (s)

# P&A WITH SALT AND SHALES



# SALT PLUGGING FIELD TESTS

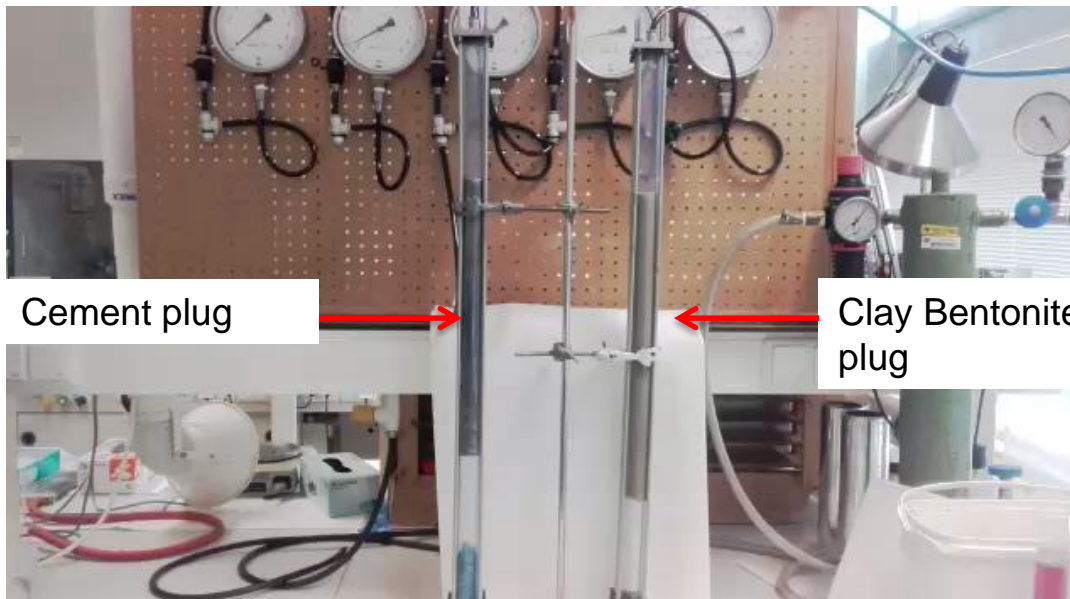


Laboratory tests on core samples- different compacted solids (salt, bentonite, barite) in different states



1. Characterization of Zechstein salt (mineralogy, microstructure)
2. Predictive modelling of convergence and sealing capacity (geo-mechanical-chemical models)
3. Monitoring convergence (3D) and sealing capacity (pressure, electrical conductivity) for model validation (special tools).
4. Post-mortem characterization of salt seal.

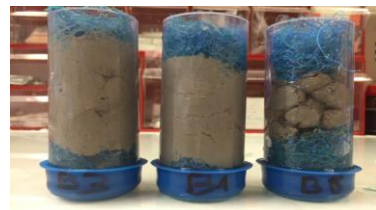
# SEALING VERSUS STIFFNESS



Cement plug

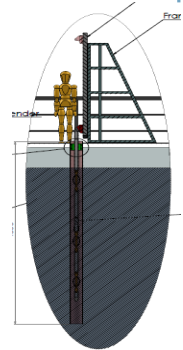
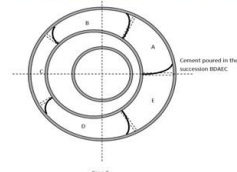
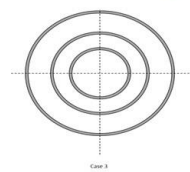
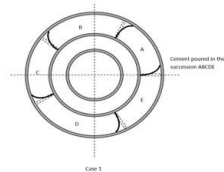
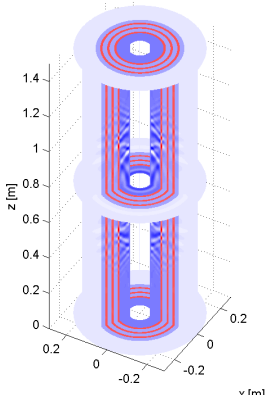
Clay Bentonite  
plug

- SPE-66496-New Abandonment Technology New Materials and Placement Techniques.pdf
- SPE-80592-Well Abandonment Using Highly Compressed Sodium Bentonite - An Australian Ca...
- SPE-115524-Plugging Wells With Hydrated Bentonite Part 2 Bentonite Bars.pdf
- SPE-176987-Plugging CSG Wells with Bentonite Review and Preliminary Lab Results.pdf

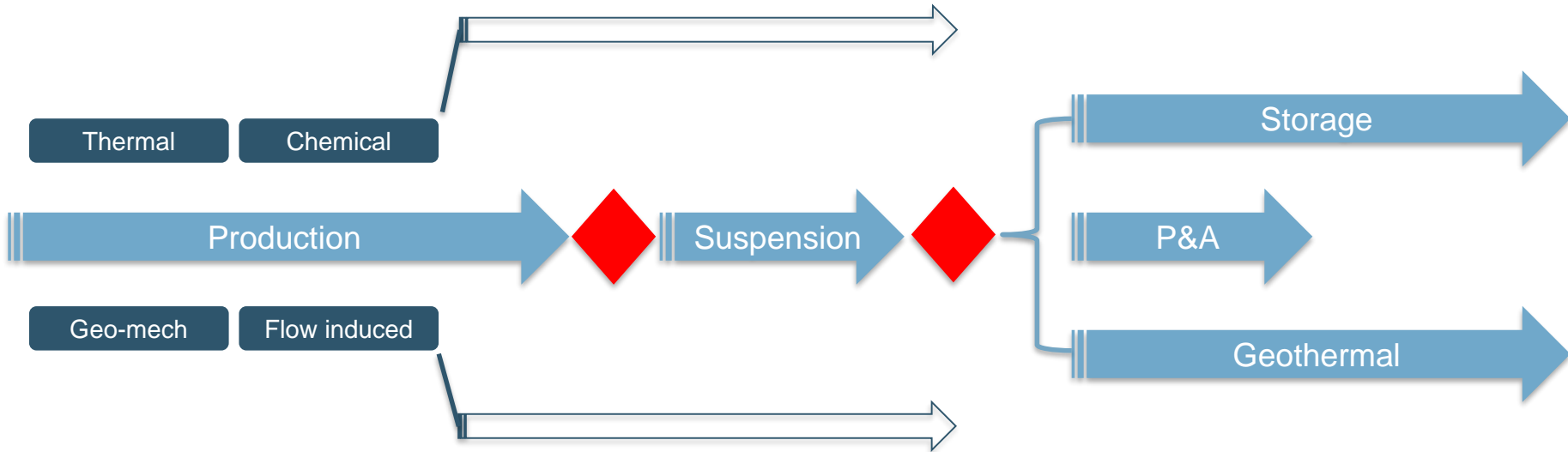




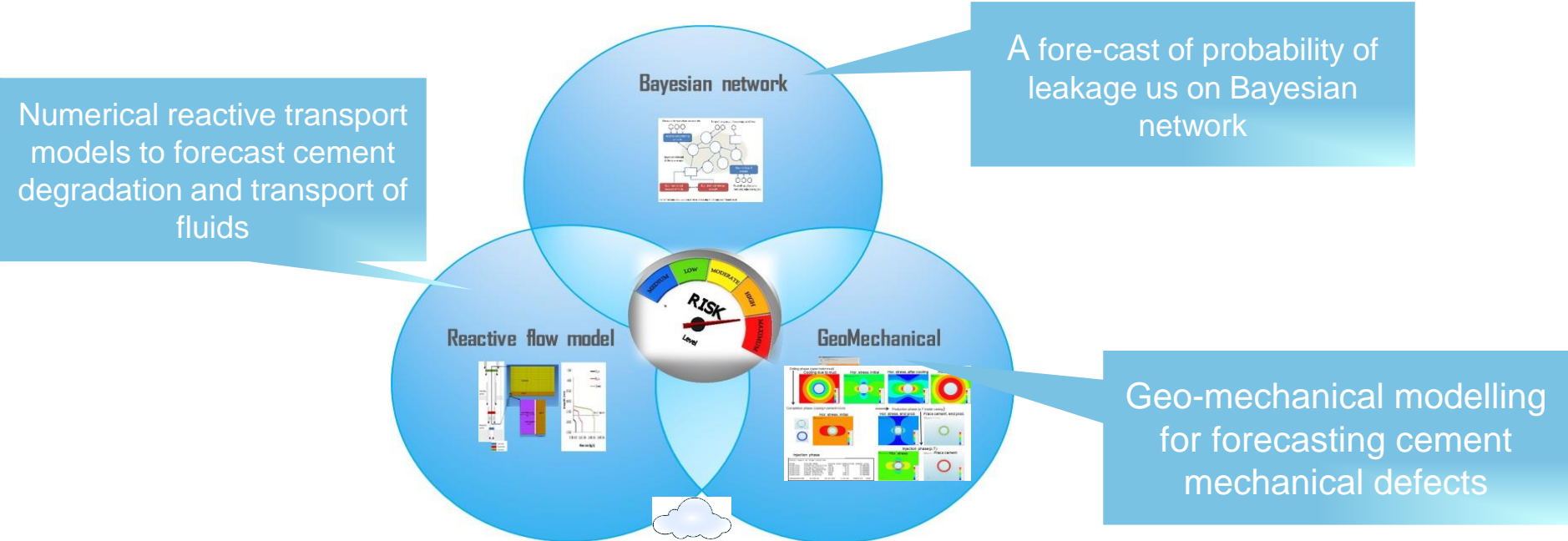
# LOGGING CEMENT INTEGRITY B- ANNULUS



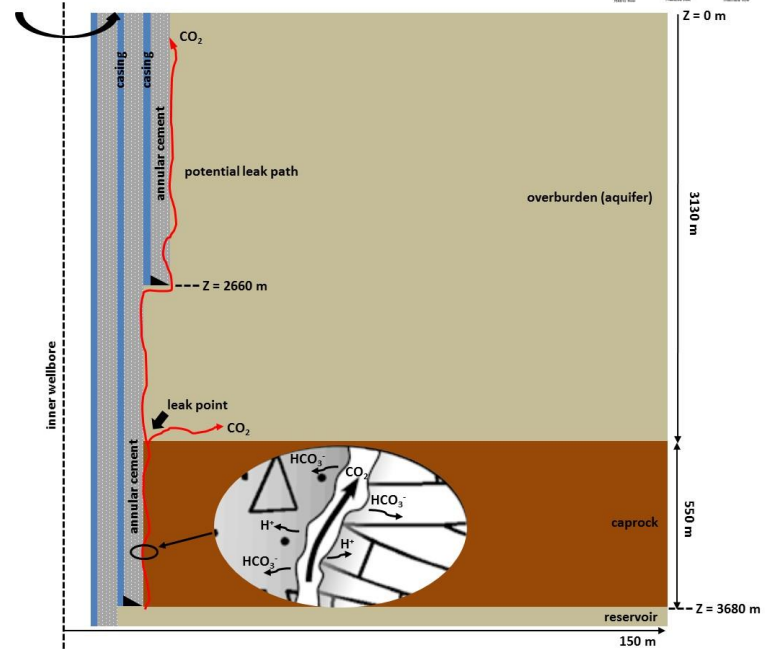
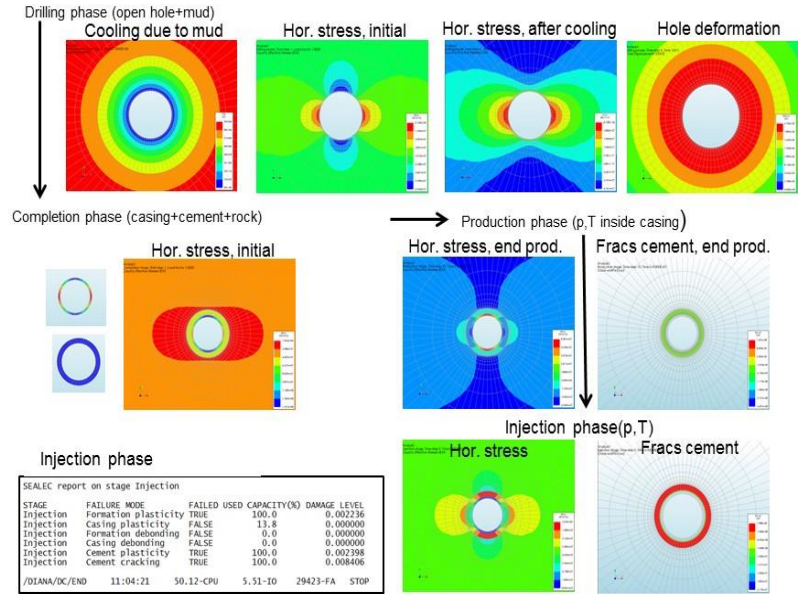
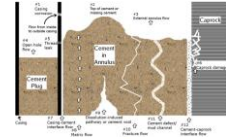
# DECISION SUPPORT: WELL ASSESSMENT



# TNO WELL INTEGRITY FORECAST SYSTEM (WIFS)



# COUPLED GEO-MECHANICAL – GEO-CHEMICAL DEGRADATION

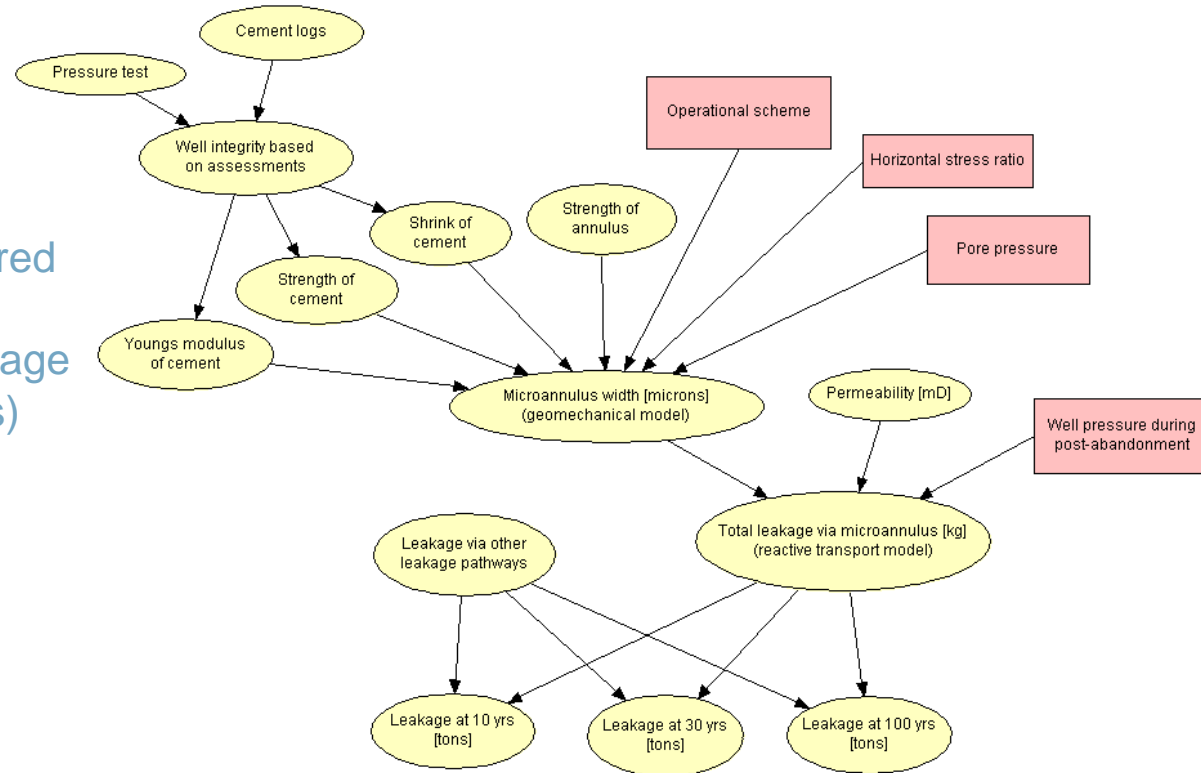




## 3 components:

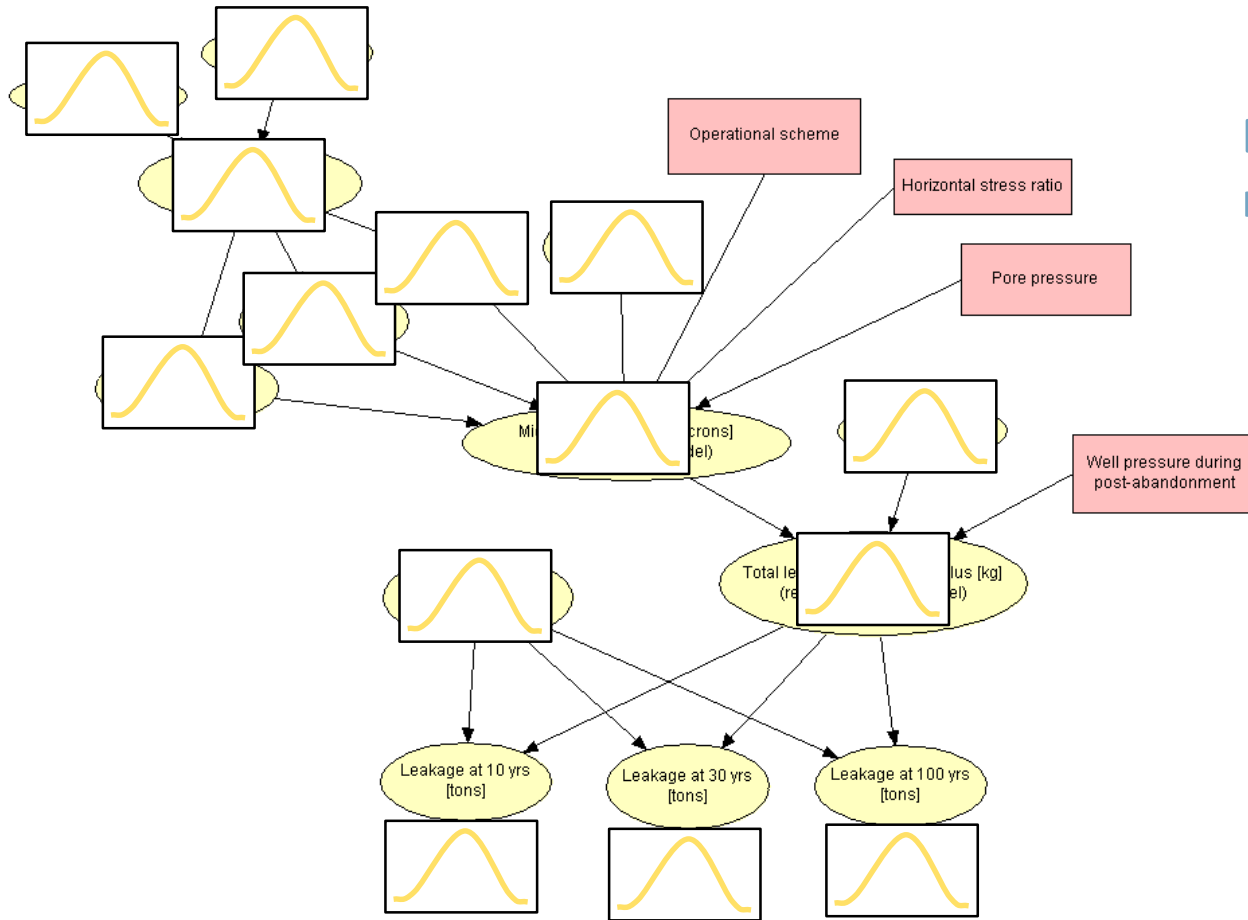
- Geomechanical model
- Reactive transport model
- Bayesian belief network

› BBN contains information acquired from the two analytical models to probabilistically estimate well leakage after abandonment (bottom nodes) due to its life during operation.



## Legend:

- User-selected values
- Probabilistic values



### Example probabilistic results:

- Leakpaths width after geomechanical model
  - E.g. 40% chance the micro annulus is 250 – 500  $\mu\text{m}$
- Leakage rate
  - E.g. 60% chance the leakage rate is 0 – 0.5 kg/year
- Amount of leakage
  - E.g. 30% chance leakage is between 1.5 and 12 tons after 30 years

# ADVANTAGES OF THE MODEL

## Benefits of methodology

- Sensitivity analyses** – determine the threshold value of the inputs where well re-use would become profitable
- Value of information** – with monetization of the inputs, you can determine the max you should pay to gain information about one of the nodes
- Coupling of models** – geomechanical and geochemical model are developed and integrated together

## Takeaways

- Combines analytical models with probabilistic methods
- Assesses probability of leakage after certain duration
- Integral understanding for a quantitative risk assessment

## Potential future applications to various re-use cases. Judge well integrity for:

- Natural gas
- Geothermal
- CO<sub>2</sub> storage

**INFORMATION OPEN JIP PROJECT RESTORING  
FORMATION SEALING OF WELL BORES**

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