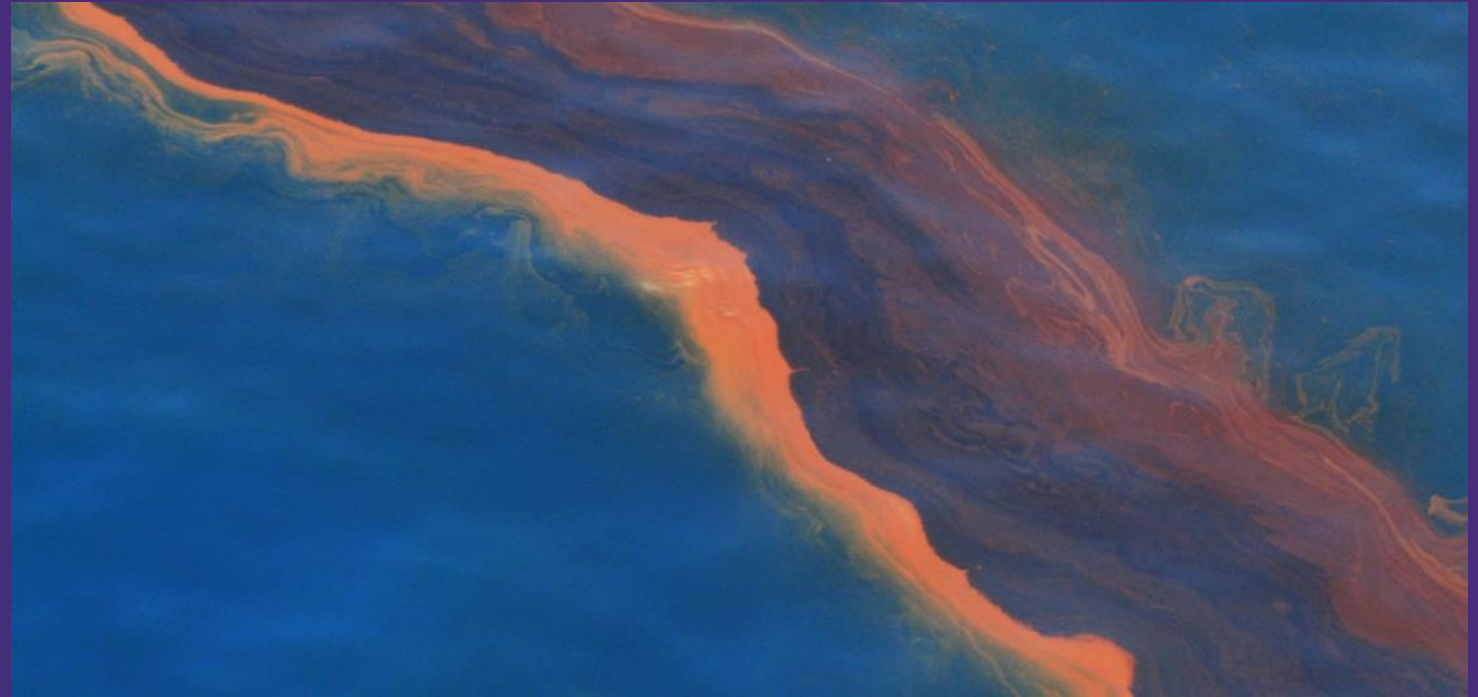




Leaky Wellbores: How They Impact Us and What We Can Do About Them

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Petroleum Engineering

Louisiana State University
February 25, 2021



Source: National Oceanic and Atmospheric Administration (NOAA) -
<https://www.noaa.gov/noaa-launches-website-holding-millions-chemical-analyses>

Biography: Research Interests

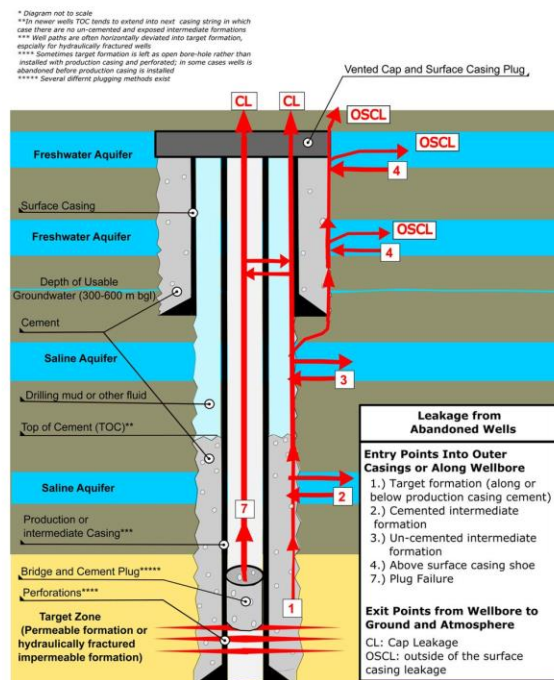
- Reactive Transport and Thermal-Hydrological-Mechanical-Chemical (THMC) Modeling for Energy and Environment
 - ❖ Wellbore Integrity - Cement-Rock-Fluid Interactions
 - ❖ Gas Hydrates
 - ❖ CO2 sequestration
 - ❖ Geothermal energy storage and production
- Basin-scale Hydrogeology – coupled heat flow, fluid flow and solute transport
- Integrated geology and subsurface engineering
- Broad range of Petroleum Engineering applications in Reservoir and Production Engineering, Worst Case Discharge, Geomechanics



What is a leaky well?

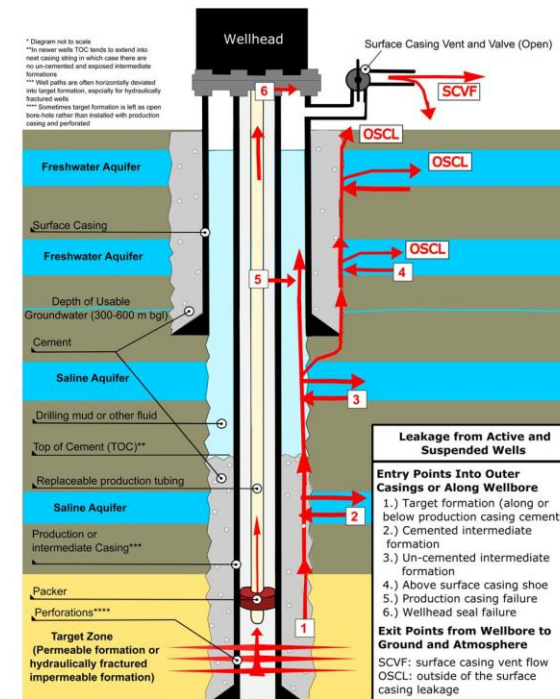
Leaky wellbores

Schematic of an abandoned well and leakage pathways classified according to entry and exit points along the wellbore.



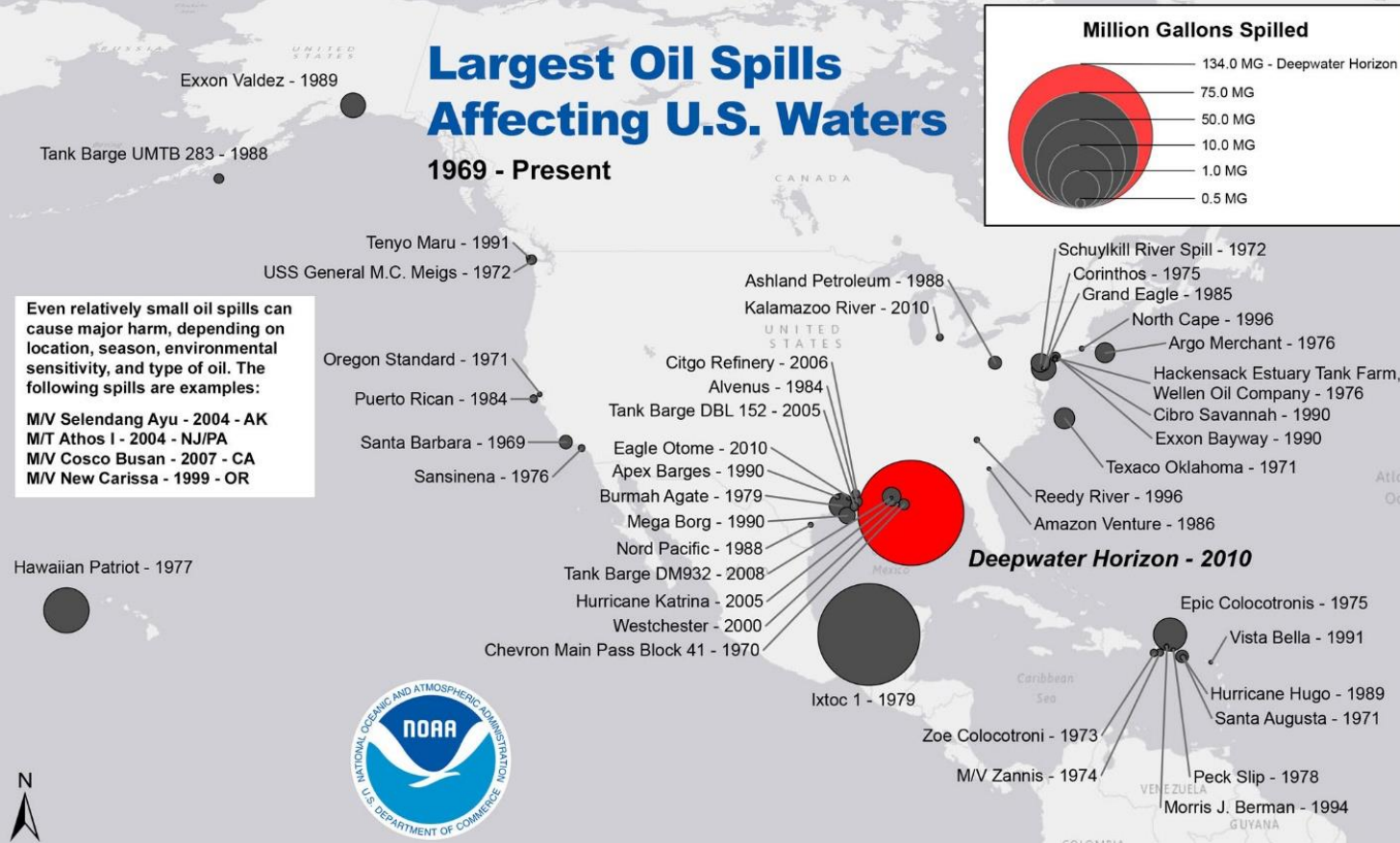
Joshua Wisen et al. PNAS 2020;117:2:913-922

Schematic of an active well with leakage pathways classified according to entry and exit points along the wellbore.



Joshua Wisen et al. PNAS 2020;117:2:913-922





Source: NOAA - <https://response.restoration.noaa.gov/about/media/where-find-orr-and-other-noaa-information-deepwater-horizon-oil-spill.html>

Source: NOAA - https://response.restoration.noaa.gov/sites/default/files/2015_largest-oil-spills-us-waters_noaa.jpg

Occurrence – Land and Sea; Impacts - Small and Big



Source: NOAA - <https://darrp.noaa.gov/oil-spills/deepwater-horizon>

Deepwater Horizon

Where Did the Oil Go?

Beaches and Other
Recreational Uses

Marsh and Other
Nearshore Habitat

Birds

Beach Habitat

Fish and Water
Column Species

Sea Turtles

Marine Mammals

Deep-sea
Communities



© 2015 NOAA. Illustration by Kate Sweeney
Adopted from the 2016 Deepwater Horizon Final Programmatic Damage Assessment and Restoration Plan and Final Programmatic
Environmental Impact Statement; Figure 1.5-1

Conceptual Model of Arctic Oil Spill Exposure and Injuries

Human Uses
Humans rely on
natural resources
in the Arctic.

OIL IMPACT
Oil could affect cultural,
subsistence, recreational
and passive uses
of natural resources.

Top Predators
Marine mammal and bird populations
are of global significance.

OIL IMPACT
Oil can produce health effects
and degrade food web.

Ice Habitat
Seasonally important
source of production,
habitat for
marine mammals.

OIL IMPACT
Sensitivity to oiling
is poorly studied.

**Wetlands,
low coastal
tundra,
lagoons:**
Provide refuge,
nesting, and
spawning areas.
Highly productive.

OIL IMPACT
Oiled, degraded or eroding
habitat reduces productivity.

Pelagic Zone
Productive area
for food web.

OIL IMPACT
Surface and dispersed oil
affects food web.
Fish eggs and larvae
are especially sensitive.

Benthos
Can be highly
productive,
important in
cycling nutrients.

OIL IMPACT
Oil in sediments
reduces productivity
and affects food web.

Impacts of an Arctic oil spill will vary
due to environmental conditions,
spill severity and response capacity.



© 2013 NOAA. Illustration by Kate Sweeney

https://www.fisheries.noaa.gov/feature-story/restoring-gulf-10-years-after-deepwater-horizon-oil-spill?utm_medium=email&utm_source=govdelivery

https://response.restoration.noaa.gov/sites/default/files/arctic-food-webs-human-uses-oil-impacts-illustration_noaa_katesweeney.jpg

2/24/2021

What can we do about them?

RESPONDING TO OIL SPILLS ON SHORE



1 SHORELINE FLUSHING/WASHING

Water hoses can rinse oil from the shoreline into the water, where it can be more easily collected.

2 BOOMS

Long, floating, interconnected barriers are used to minimize the spread of spilled oil.

3 VACUUMS

Industrial-sized vacuum trucks can suction oil from the shoreline or on the water surface.

4 SORBENTS

Specialized absorbent materials act like a sponge to pick up oil but not water.

5 SHORELINE CLEANERS & BIODEGRADATION AGENTS

Chemical cleaners that act like soaps may be used to remove oil, but require special permission. Nutrients may be added to help microbes break down oil.

6 BURNING

Also referred to as "in situ burning," freshly spilled oil can be set on fire, usually while it's floating on the water surface and sometimes on oiled marsh vegetation, in order to effectively remove it.

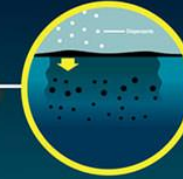
7 MANUAL REMOVAL

Cleanup crews using shovels or other hand tools can pick up oil from the shoreline. This method is used especially when heavy machinery cannot reach an oiled shore.

8 MECHANICAL REMOVAL

When there is access, heavy machinery, such as backhoes or front-end loaders, may be used.

RESPONDING TO OIL SPILLS AT SEA



DISPERSION

Chemical dispersion is achieved by applying chemicals designed to remove oil from the water surface by breaking the oil into small droplets.

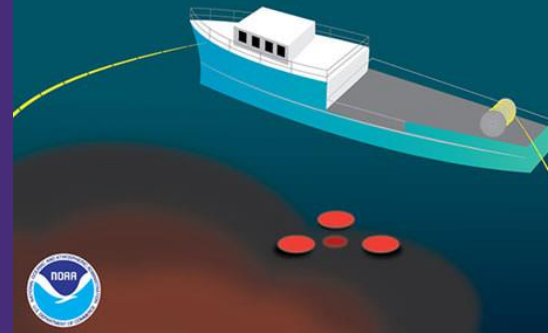


BURNING

Also referred to as in situ burning, this is the method of setting fire to freshly spilled oil, usually while still floating on the water surface.

BOOMS

Booms are long, floating barriers used to contain or prevent the spread of spilled oil.



SKIMMING

Skimming is achieved with boats equipped with a floating skimmer designed to remove thin layers of oil from the surface, often with the help of booms.



Source NOAA -

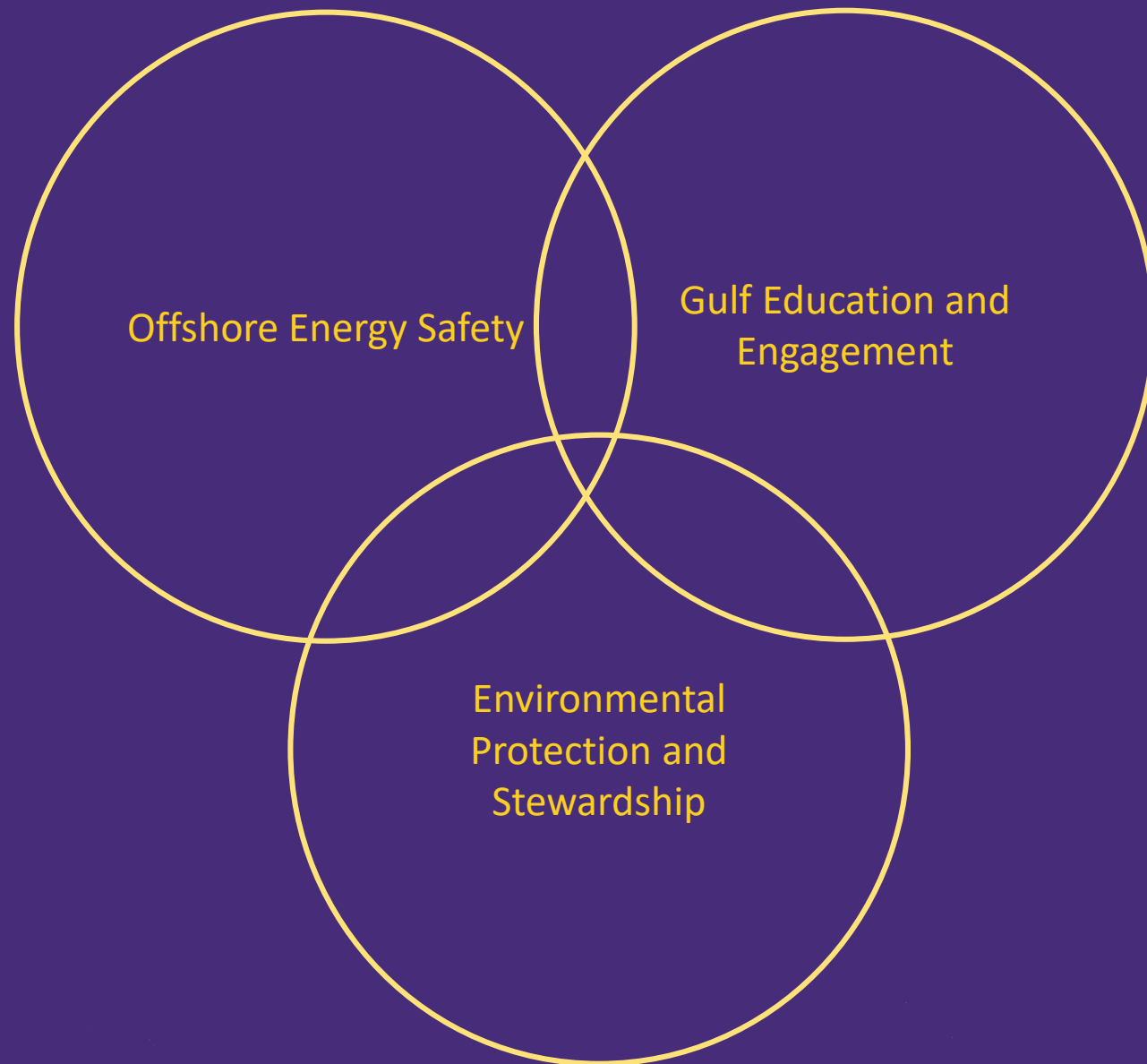
<https://oceanservice.noaa.gov/facts/spills-cleanup.html>

**But.....what could we
do before they occur?**

A preventative strategy

= Responsible energy engineering

Research and Teaching Areas in Relation to GRP Initiatives



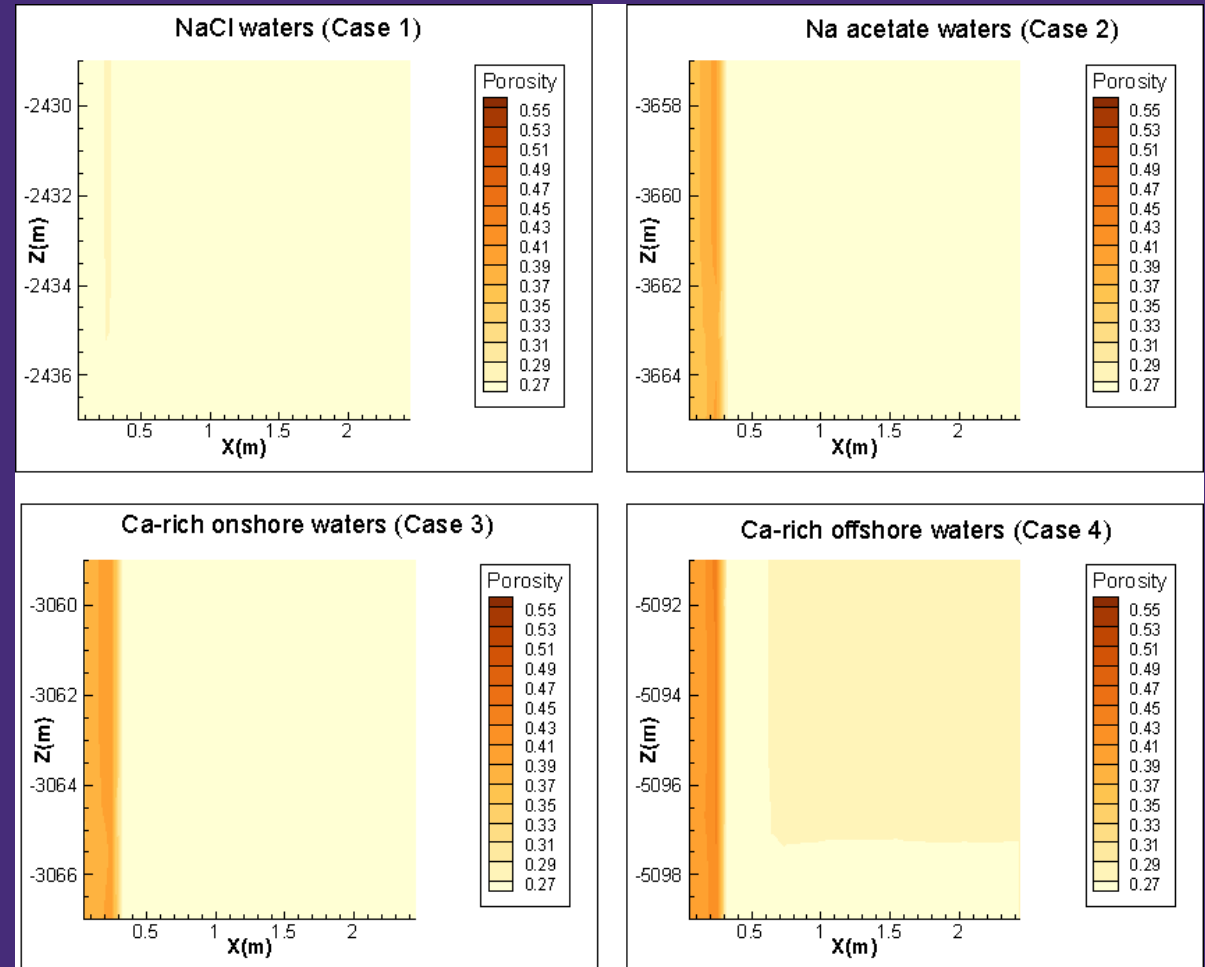


Research Questions

- How long does cement last under subsurface conditions? When can they start losing “integrity”, becoming “leaky”? Can we “predict” longevity?
- How much oil could spill? From leaks. From blowouts.
- If oil spills, how long will they remain in the sediments/contaminated zones?
- Can we predict leaks and possible fractures ahead of time?

Example 1: Predicting Longevity

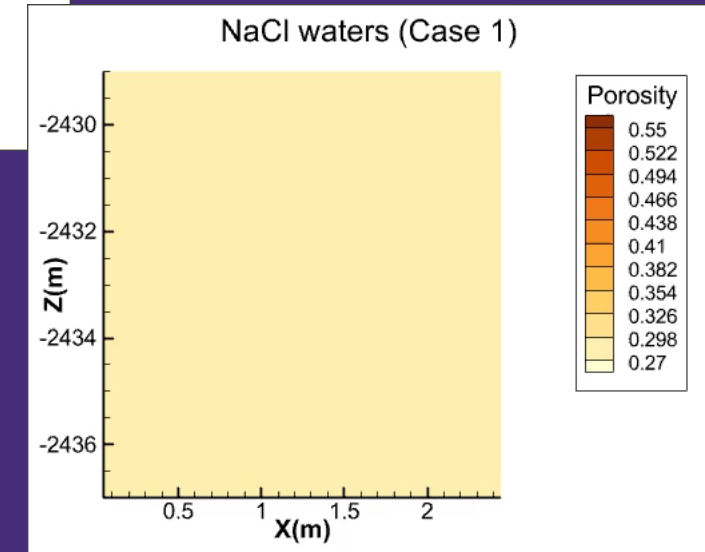
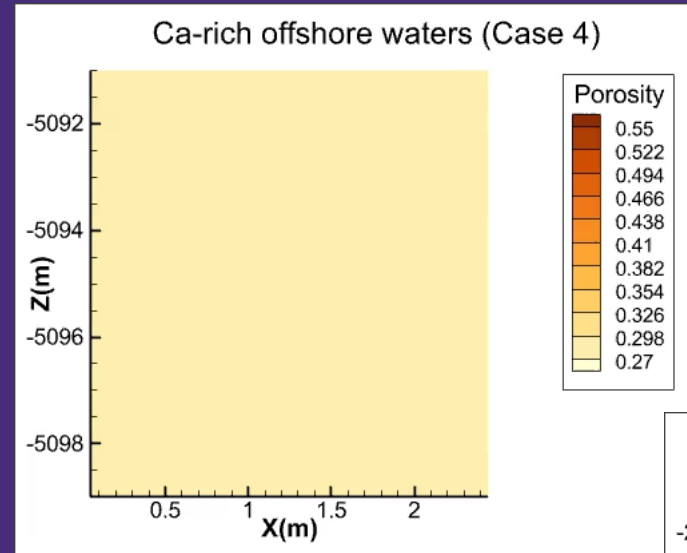
- Use physics (flow and transport) + chemistry (composition) + math (modeling) to study how long cement/plugs last under subsurface conditions?
- Cement + Brine Reactions;
Cement + Rock + Brine Reactions.



Reproduced with permission from T. Ajayi and I. Gupta "Long term assessment of the geochemical integrity of offshore wellbore cement– results from numerical modeling", Journal of Petroleum Science and Engineering, Volume 201, 2021, 108443, ISSN 0920-4105, <https://doi.org/10.1016/j.petrol.2021.108443>. Elsevier.

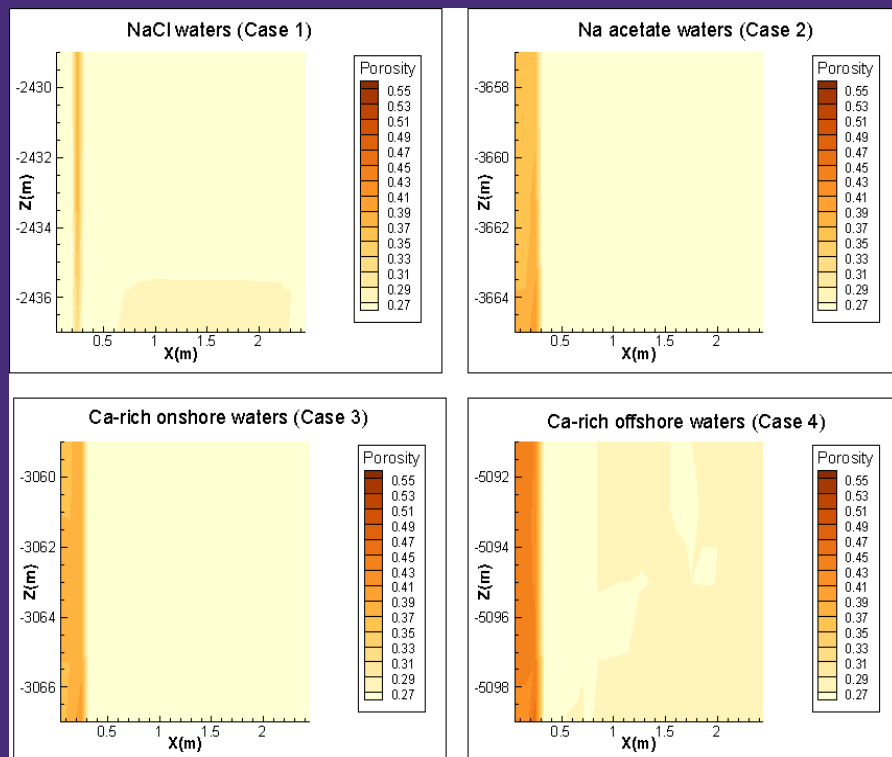
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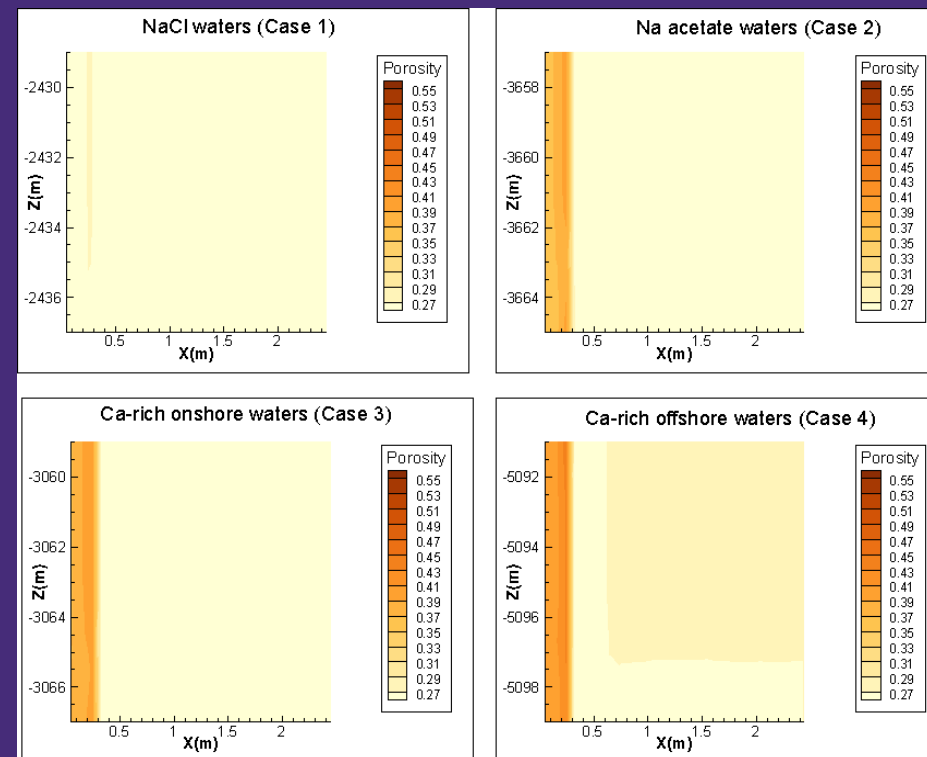


Temitope Ajayi PhD Research

Example 1: Predicting Longevity



Cement, shale, brines



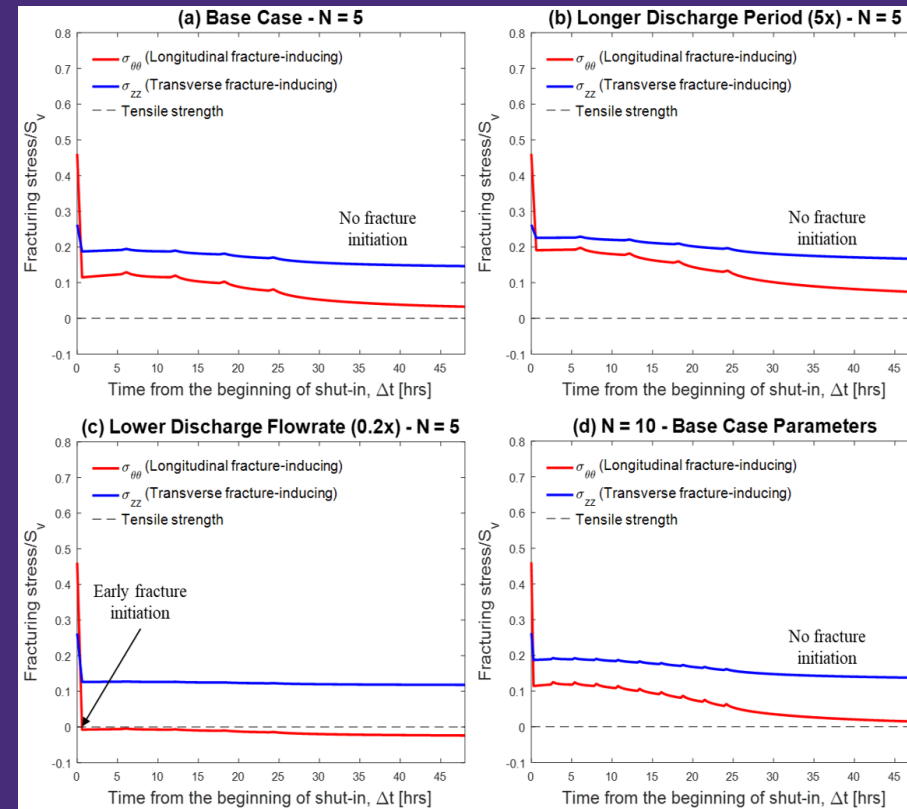
Cement, sandstone, brines

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Example 2: Predicting Fracturing

- Use physics (flow + mechanics) + math (modeling) to study if fractures can initiate after blowouts occur – but do this before even drilling a well to avoid/minimize chances of it from occurring altogether.

Longitudinal ($\sigma_{\theta\theta}$, red lines) and transverse (σ_{zz} , blue lines) fracturing stresses for four different combinations of shut-in parameters. Fracture initiation takes place when either of the two lines becomes more negative than the black dotted-line, indicating the tensile strength of the rock, T . (a) Base Case parameters with number of shut-in steps, $N = 5$, (b) a 5-fold increase in the discharge period preceding the capping stack shut-in (5 days, compared to 1 day) compared to the Base Case, (c) a 5-fold decrease in the discharge flowrate (31,008 barrels/day, compared to 155,040 barrels/day) compared to the Base Case, and (d) Base Case parameters with $N = 10$. Following this evaluation, an optimal capping stack shut-in strategy can be selected such that any fracture initiation will be prevented. This analysis can be performed prior to drilling considering relevant scenarios for draft contingency plan in the event of a blowout. This image is reproduced with permission from the Society of Petroleum Engineers Copyright Clearance Center. Reference: Michael, A., and Gupta, I. (2020). Fracture Prevention Following Offshore Well Blowouts: Selecting the Appropriate Capping Stack Shut-In Strategy. Society of Petroleum Engineers. *SPE Drilling & Completions*, doi:10.2118/199673-PA.

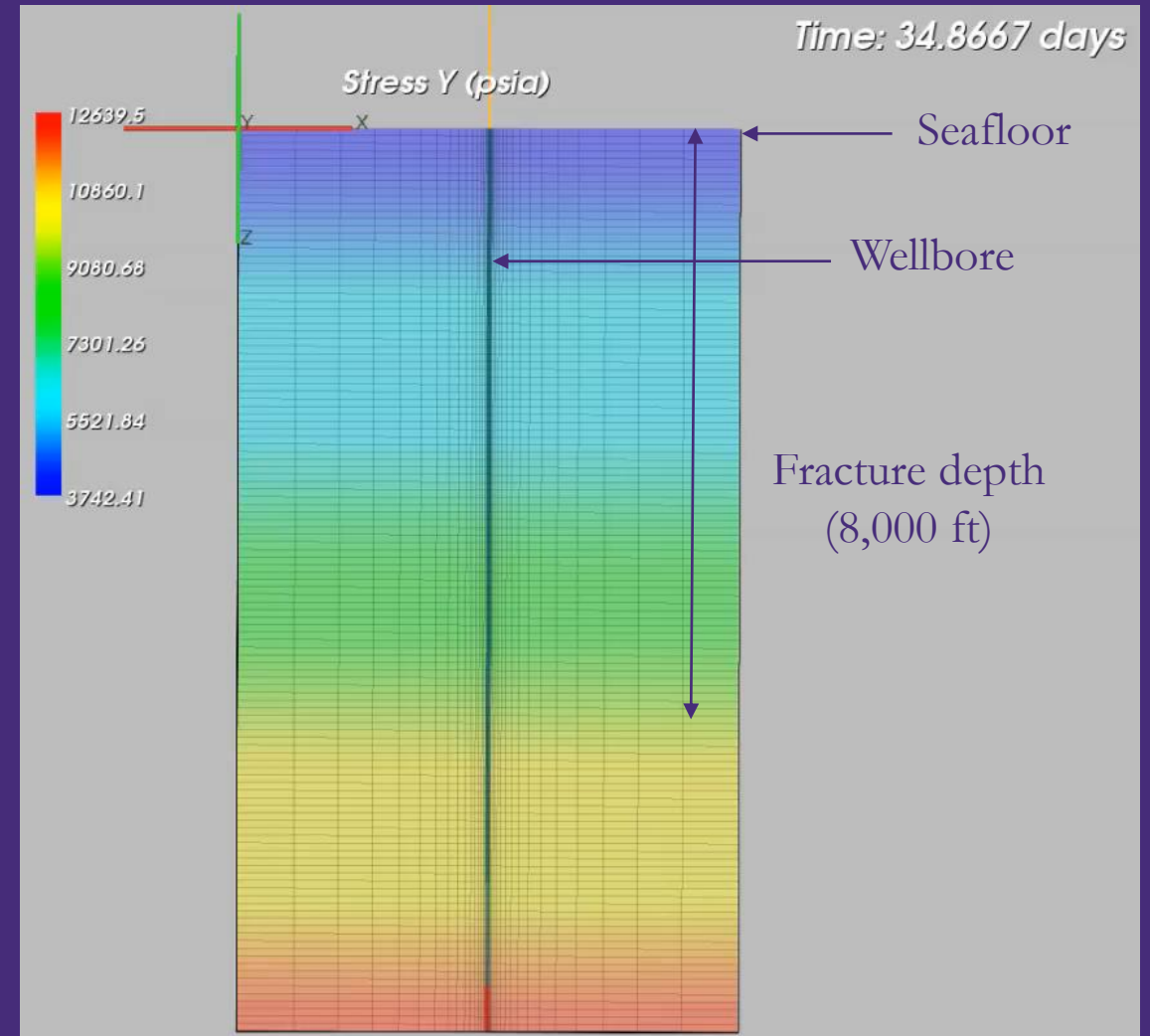


Andreas Michael PhD Dissertation

Example 3: Predicting Broaching

- Use physics (flow + mechanics) + math (modeling) to study if fractures can propagate after blowouts occur – but do this before even drilling the well.

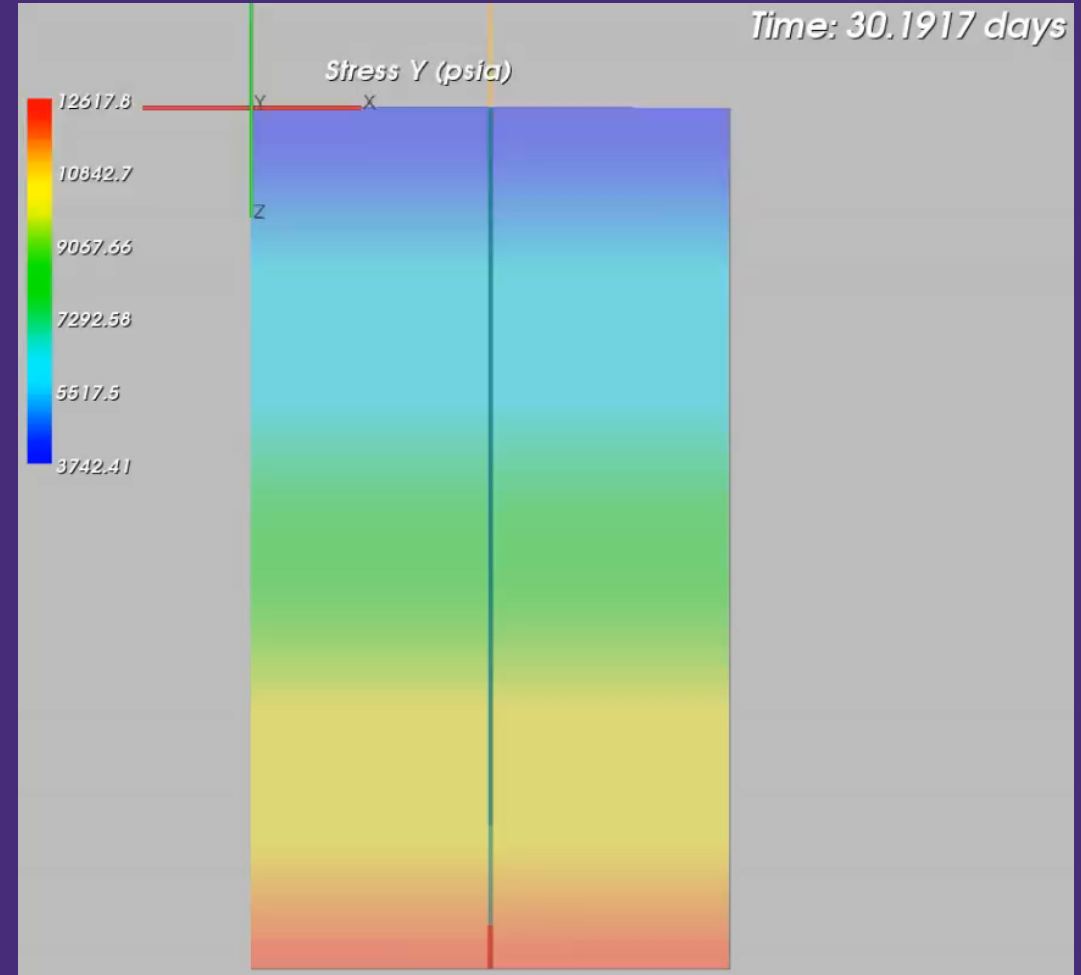
Youssuf Elnoamany MS Thesis (2021). Software license donation - Petroleum Experts (REVEAL).



Example 3: Predicting Broaching

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Youssuf Elnoamany MS Thesis (2021). Software license donation - Petroleum Experts (REVEAL).





Conclusions

- Using science, math, engineering and technology we can study:
 - leaks and spills from oil and gas wellbores/pipelines,
 - their impact on health, safety and environment,
 - clean up processes,
 - and equally important – employ predictive, preventative strategies for responsible energy engineering.

Is this all we do or can do?

NO!

We do much, much more!!!

But, I hope I have conveyed to you that:

**Responsible Energy Engineering is
Important for our Health, Safety and
Environment.**

LSU References:

Ajayi, T. and Gupta, I. “Long term assessment of the geochemical integrity of offshore wellbore cement– results from numerical modeling”, *Journal of Petroleum Science and Engineering*, Volume 201, 2021, 108443, ISSN 0920-4105, <https://doi.org/10.1016/j.petrol.2021.108443>. Elsevier.

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Questions