Shale gas operation
& water resource preservation

VEOLIA
ENVIRONNEMENT

PECC, November 2013

Part I – Veolia and the oil and gas industry

Water, a very sensitive raw material for oil and gas firms

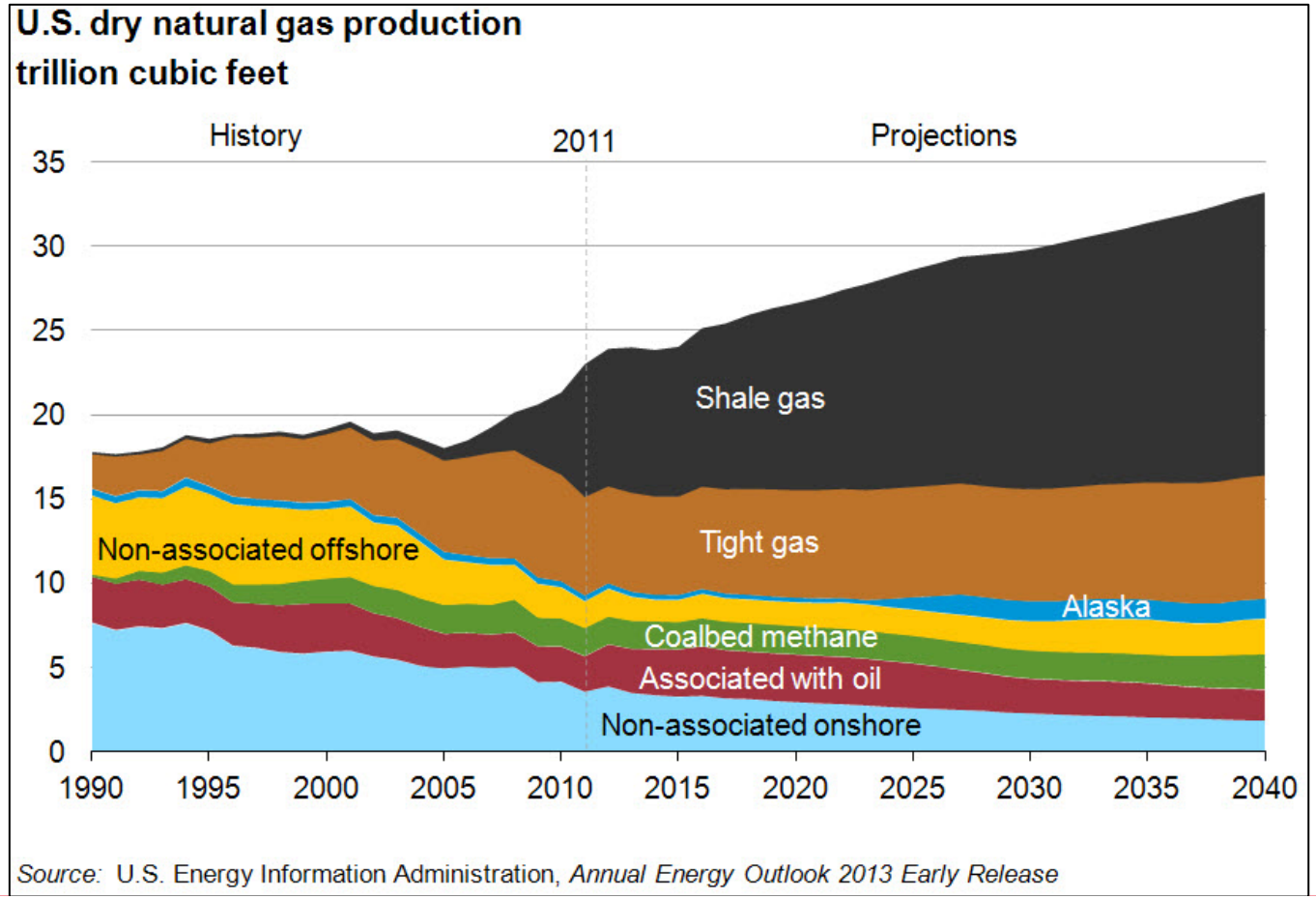
- Oil and gas firms use more of water than any other fluid!
  - it takes 3 to 5 barrels of water to produce 1 barrel of oil, and up to 10 barrels for the most mature fields;
  - it takes 30 to 40 m^3 of water to produce 1 m^3 of unconventional gas!
- Water and energy are intimately bound up with each other.
  - You cannot produce energy without water—and vice versa—and both need to confront one of the great questions of our age, namely scarcity.
  - In a world of dwindling resources, the search for more efficient ways to use water is now a central concern for energy producers.
- For the oil and gas industry, water is not just another commodity: it is a key means of production. Which is why Veolia tasks encompass:
  - guaranteeing reliable operations and protecting the environment,
  - boosting the industry's competitiveness and supporting its economic development.

The linkage between economic and environmental performance is the bedrock of Veolia services to industrial customers

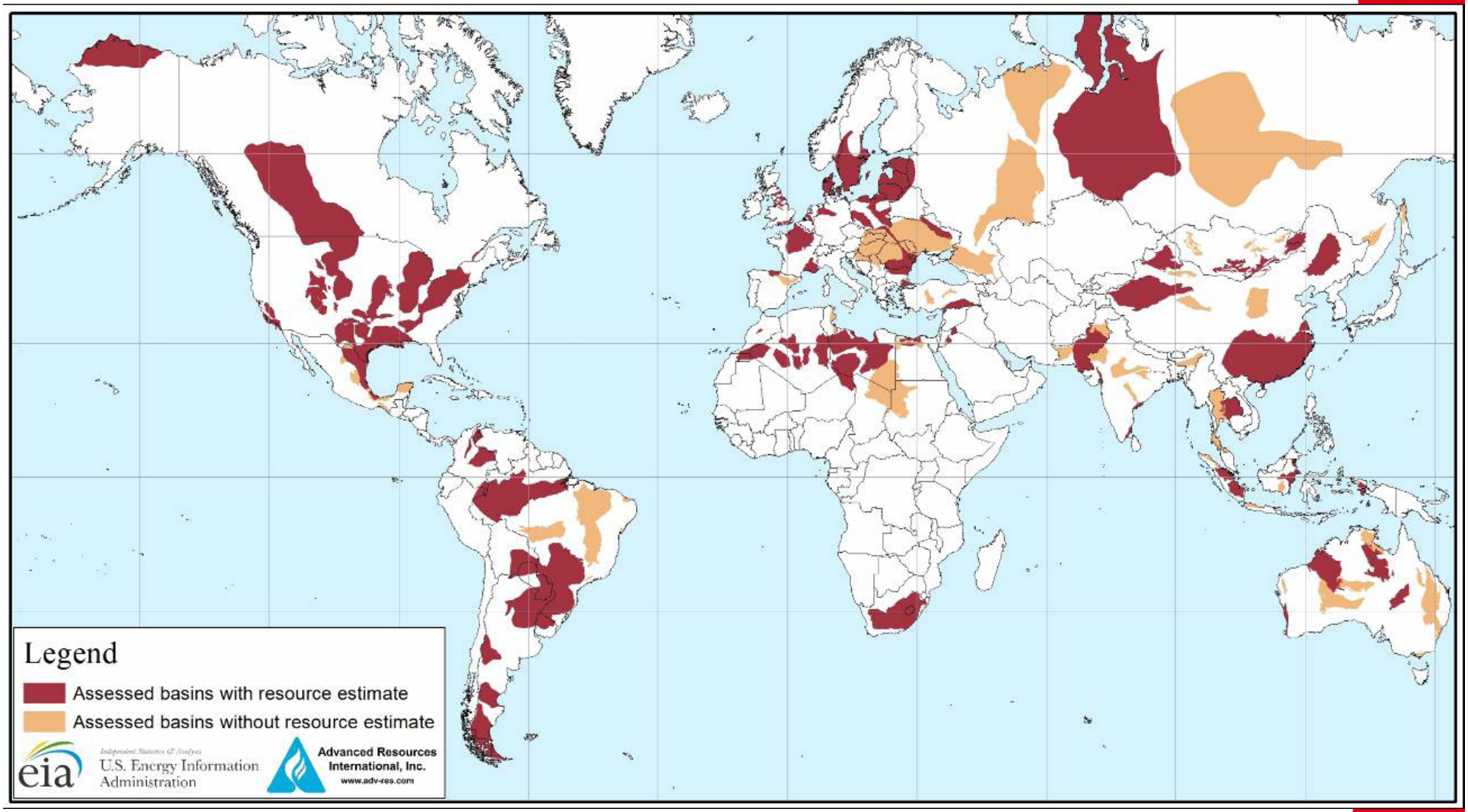
- Veolia is one of the few companies able to supply water treatment solutions at every step in the **conventional hydrocarbons** production chain, from exploration to refining, via oil and gas field operations and shipment.
- Veolia is one of the few companies proficient in all of the techniques required to exploit **shale gas** cleanly, with no water pollution, and recycling all of the water used.
  - These specific technologies emerge at the crossroad of our two main activities: water decontamination and hazardous waste treatment.
  - Since 7 years, Veolia is involved in the business of unconventional hydrocarbons .
- Our relationship with industrial customers used to be that of a technical provider called in to tackle a specific problem. Today, our role is that of a true partner, working with them to increase their competitiveness.
  - The more closely we work with our customers, the greater the value added we can provide them.
  - For the oil and gas industry, we are no longer merely a supplier or subcontractor, but a genuine partner.

Veolia repositioning on new activities

- Our strategy consists in selecting activities for which there is a sizable, solvent demand, and where our expertise differentiates us from our competitors.
- One of the most important of these new activities is shale gas extraction.



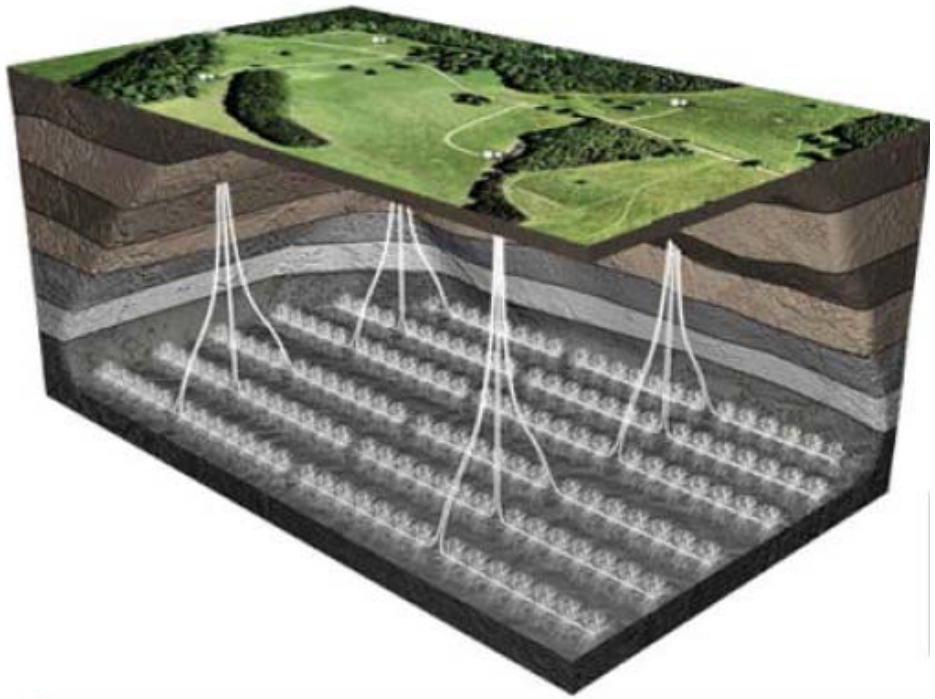
Map of basins with assessed shale oil and shale gas formations, as of May 2013



Source: United States basins from U.S. Energy Information Administration and United States Geological Survey; other basins from ARI based on data from various published studies.

Part II – Reconciliating shale gas operation and water resource protection

Main environmental issues (1)



- Landscape:
  - To produce the same volume of gas, it is necessray to operate 200 more wells with shale gas fields than with conventional gas fields.
  - Surface footprint could be reduced thanks to pad drilling.
- Noise for neigbours

Drilling and hydraulic fracking period: a few weeks per well. The largest footprint

Shale gas production period: 10 to 25 years - Low impact

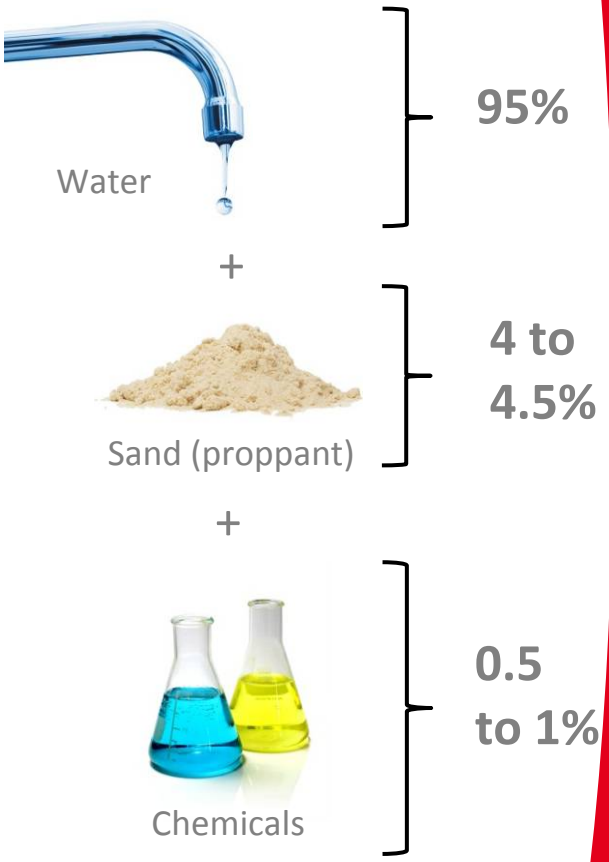
After production.

Source: Total, July 10th, 2013 - Veolia Sustainable Development Observatory

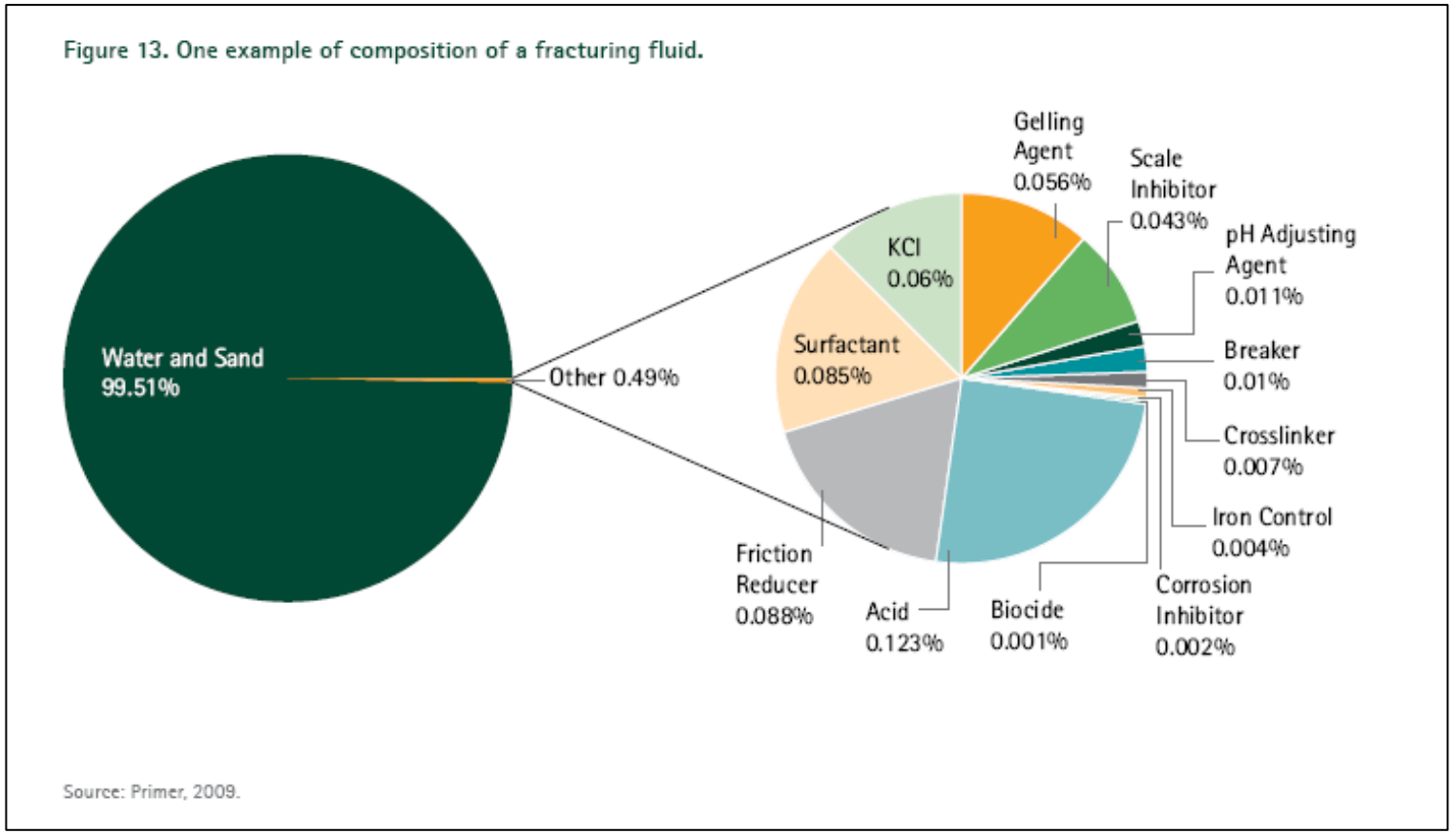
Main environmental issues (2)

- Water:
  - **High water consumption:** 10,000 to 20,000 m^3 per well.
  - **Potential contamination (by gas or chemical additives) of the water tables crossed by wells, in case they are not perfectly isolated.** This is a concern of the whole industry, whatever the product (oil, natural gas, unconventional gas, geothermal activities…), because it may heavily reduce energy production.
  - **Injection of chemical additives.**
    - ➜ In 2005-2009, 2,500 chemical products were used in the US by oil and gas firms.
    - ➜ Many of them are common, other are toxic (eg. benzene or lead).
  - **Potential contamination of rivers and lakes.**
    - ❖ One third of the fracturing fluid returns to surface.
    - ❖ It may be contaminated by the release of metals (lead, copper…), organic or radioactive elements contained in the reservoir rocks

Composition of volumes injected into wells



Example of composition of fracturing fluid



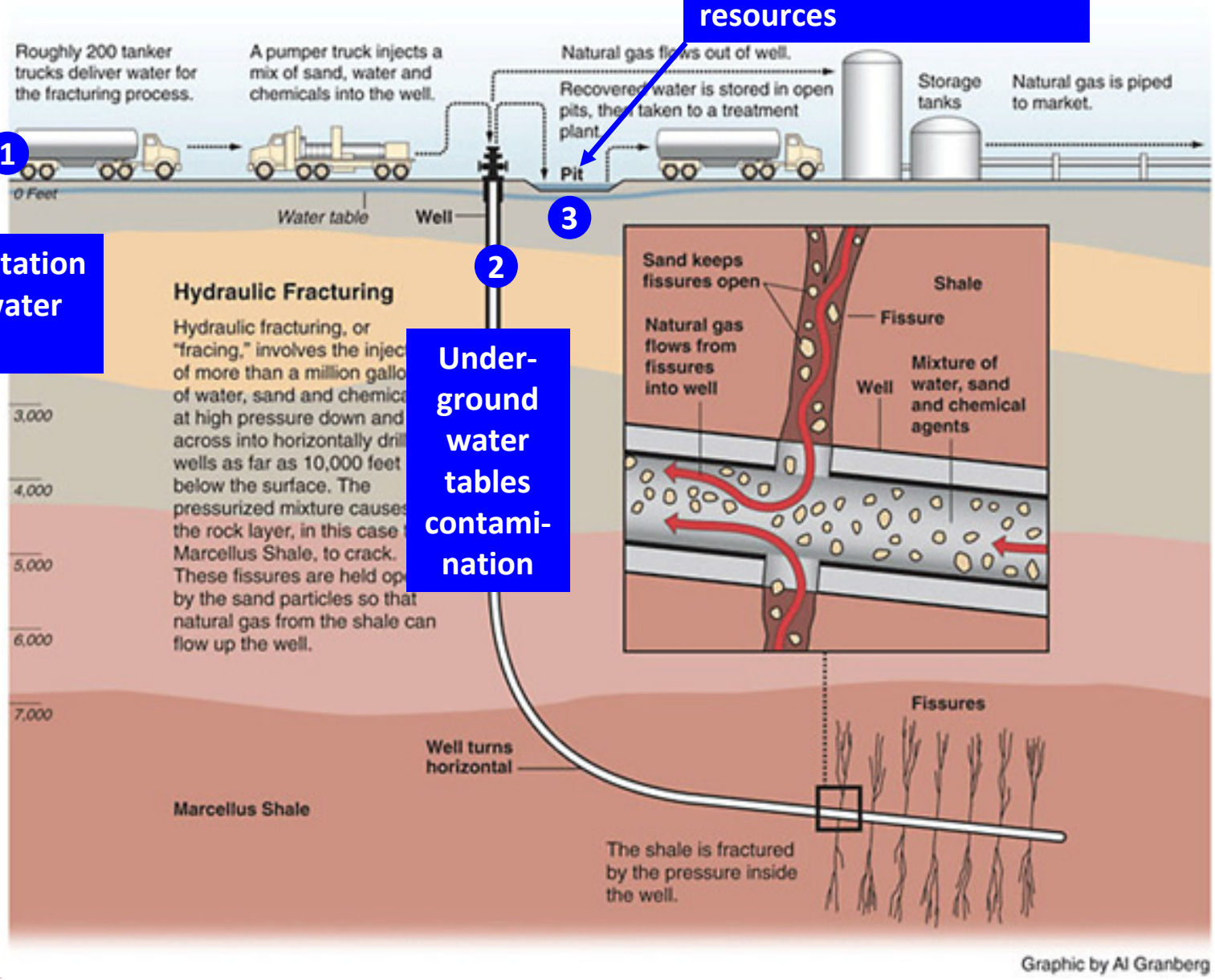
Source: Water and shale gas development, Accenture, 2012

The impact points and risks to be controlled with regards to water issues

Pollution of surface water resources

Overexploitation of scarce water resources

Under-ground water tables contami-nation



Solutions for a sustainable management of water in shale gas operation

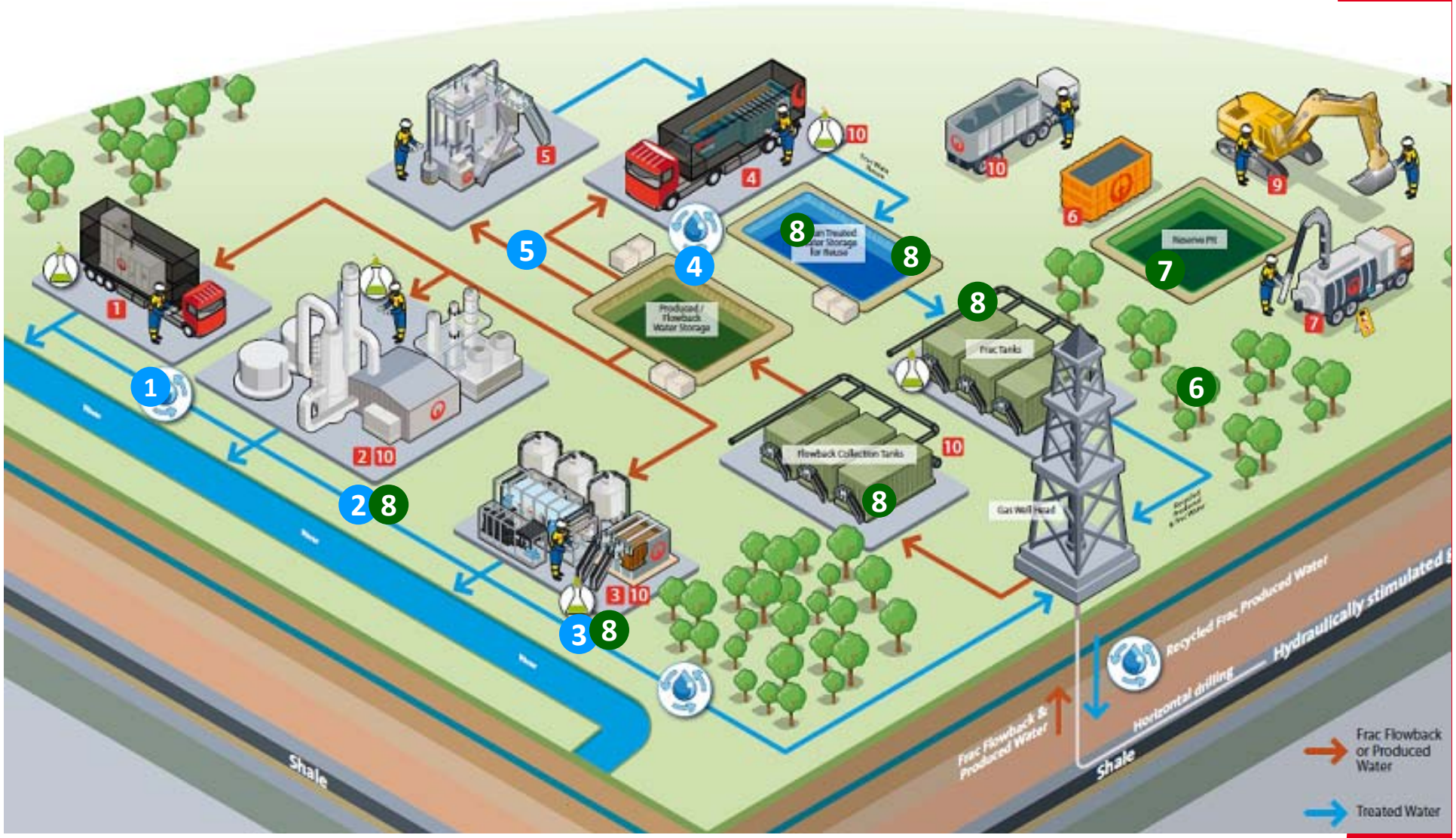
- There are various efficient technologies for depolluting wastewater
  - Removing specific salts (precipitation treatment, for instance Multiflo ™)
  - Removing all salts:
    - ➜ Membrane technology: reverse osmosis (salinity < 30,000 mg/l)
    - ➜ Thermal treatment: evaporation & crystallization (when water salinity > 30,000 mg/l)
  - Removing organic components:
    - ❖ Membrane Bio-Reactor (biological treatment and membrane separation)
    - ❖ Moving Bed Bio-Reactor
    - ❖ Macro Porous Polymer Extraction (adsorption of micro-pollutants). E.g.: Prelude project, developed in Australia for Shell.
- Criteria for treatment design:
  - Water flows to be treated during normal and pick periods versus storage capacity
  - Mobile, temporary or centralized water treatment units ?
  - Logistics and energy scheme: on-site treatment versus transportation to a centralized unit
  - The issue of final solid waste

Towards an optimization of water treatment

- Data collection and management is critical for accurate treatment design and operation:
  - Precise composition of the fracturing fluid injected
  - Chemical composition of the reservoir rocks
  - Water needs and water production forecasts

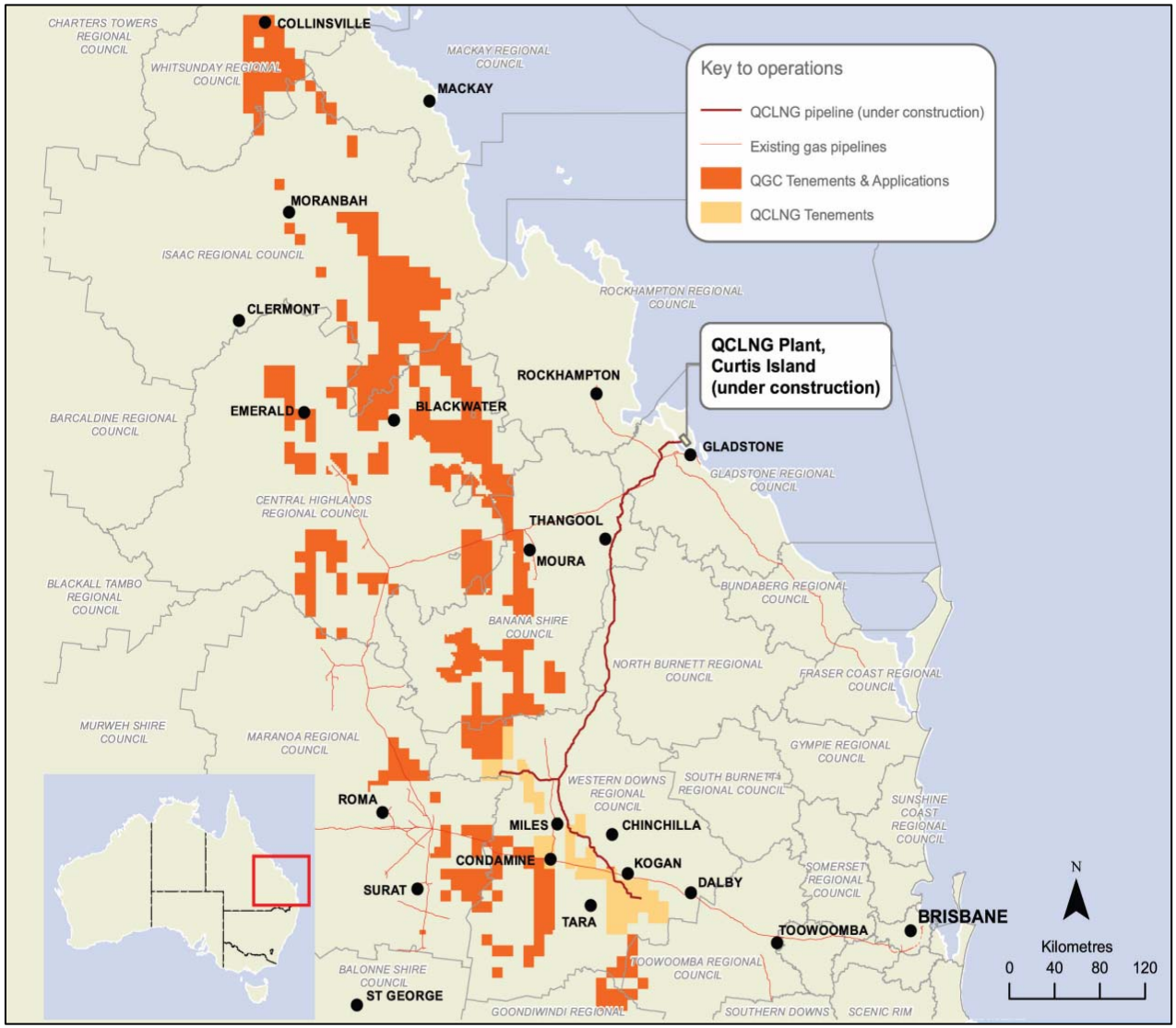
- A strong requirement for flexibility, to adapt in real time water treatment
  - Huge qualitative and quantitative variations of water to be treated;
  - The first flowback waters require a specific treatment;
  - Shale gas production could be reduced during dry season to save raw water;
  - Economic optimization relies on combining several solutions: mobile water treatment units, centralized treatment units, storage capacity, transportation means (pipes, trucks), etc.;
  - Location and capacity of outlets:
    - For raw water, treated water, reused water
    - For final waste

Economic optimization relies on a combining several solutions



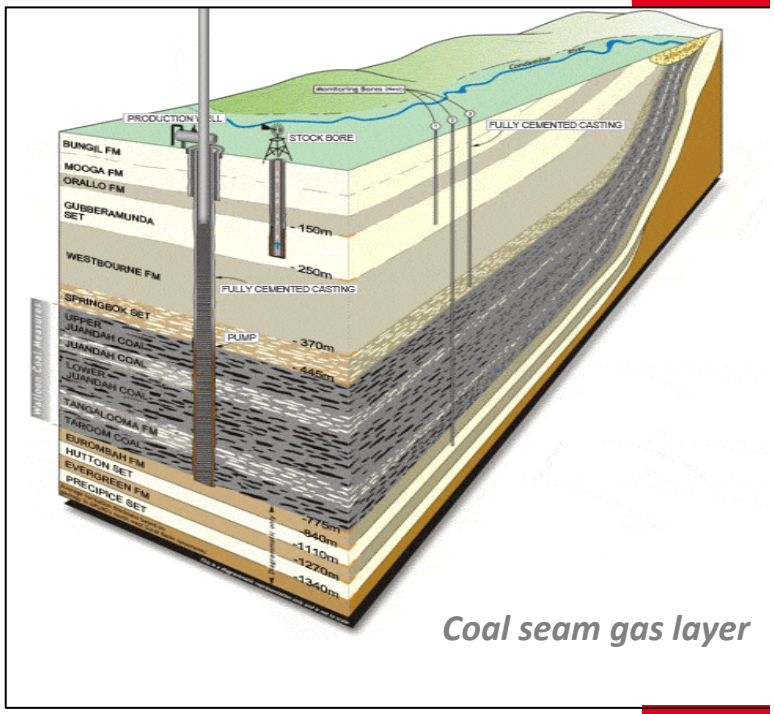
1. Mobile water treatment (evaporation) → discharge / reuse
2. Water treatment (evaporation & crystallization) → discharge / reuse
3. Water treatment (reverse osmosis) → discharge / reuse
4. Mobile water treatment → reuse
5. Water treatment for odor control
6. Vacuum truck service for liquid waste
7. Soil remediation
8. Solidification

– Part III –
The Queensland coal seam gas contract



Shale gas, a national strategy for Australia

- Australia advantages and policy:
  - A huge potential: Australia hosts the 3rd larger coal gas field of the world (after US and Canada).
  - A preference for coal seam gas (> 95% pure methane)
  - A gas exportation strategy. By 2020, Australia will be the world's largest LNG exporter, produced from non conventional methods, and the state of Queensland will be the main contributor.
  - Dynamic local technological firms to improve process and performance.



Coal seam gas layer

- The Queensland Curtis LNG project:
  - Coal gas production start: 2014
  - Production of one third of Australia Liquefied Natural gas (LNG), as soon as the first step of the project is completed
  - 540 km of underground gas pipeline network to transport coal gas from Surat field to Curtis Island, where it will be liquefied
  - In the long run, 9.5 million tons of LNG exported every year to Asian countries
  - Estimated revenue of the whole project: €15 billion

Main features of the contract awarded to Veolia in 2013

- Key figures:
  - Field gas surface: 20,000 km^2
  - 6,000 wells to be drilled since 2030
  - 3 water treatment plants to be operated (under construction by GE / Lang O'Rourke and to be commissioned in 2013 and 2014)
  - 200,000 m^3 of water purified per day
  - Contractor: QGC, leader in Australian natural gas exploration and subsidiary of BG Group. BG Group is one of the 5 largest producers of unconventional hydrocarbons in the world.
  - 650 M€ revenue over the contract duration
  - 55-60 full-time employees dedicated to this contract
- Reasons of success:
  - Local implantation and track record since several years in the Queensland
  - Technical fame of infrastructure managed by Veolia : Western Corridor reuse project, Gold coast desalination plant, Sydney desalination plant, Rosehill recycling scheme…
  - High level expertise and new technologies, in particular with our subsidiary HPD specialized in evaporation / crystallization (effluent recycling rate > 99%, negligible volume of residual waste)

Field gas operation scheme and place of water in it

Export markets

Curtis Island LNG plant

Gas supply and electricity generation

Water for beneficial re-use (irrigation & power station)

Central processing plant

Water treatment plants

Gas compression station

Temporary water storage

Coal gas wells

Gas

Water

Environment, a major concern for the state of Queensland

- Very stringent environmental regulation.
- A World heritage site: the Great Barrier Reef.
- Water, the most important environmental concern
  - Water challenges: water scarcity and decontamination of heavily polluted effluents.
  - Requirement of the Queensland state before approval of the Curtis LNG project: all the water used for coal gas operation should be totally decontaminated and recycled for other uses such as irrigation or industry.
  - The water that remains (after the gas is separated at the well-head) is known as Coal Seam Gas water. It is highly concentrated in salt. It is collected from the multiple well-heads and transferred through a network of water pipes to central storage ponds, where it is safely stored before being pumped to water treatment facilities that are specifically able to deal with high salt content removal.
  - Water treatment and recycling amount to 4.5% of the total revenue of the Curtis LNG project

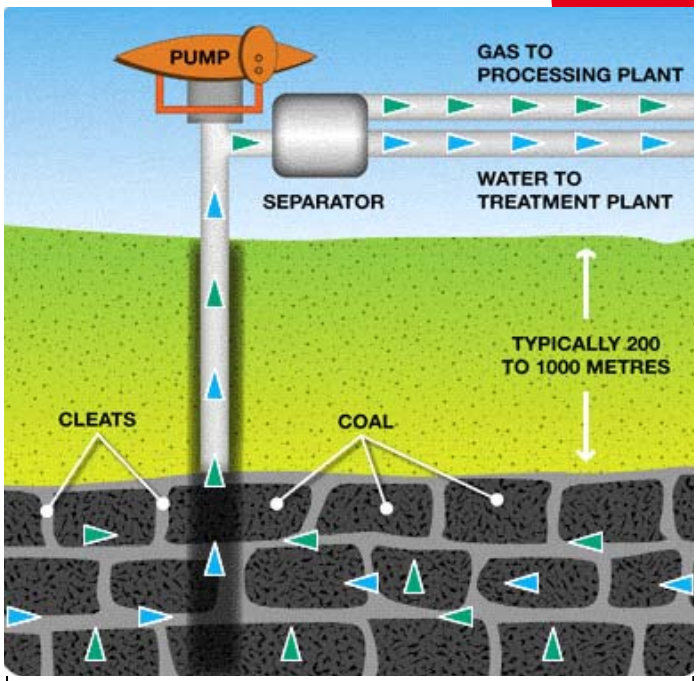


Diagram showing how coal seam gas and water are extracted

Repositioning our Company on the new frontiers of the environment business

- In neither Australia nor in the Middle East is it any longer possible to develop gas or oil fields without taking water issues extremely seriously. So the growth potential for the water management and equipment market is enormous in these regions of the world.
- The Queensland 20 year contract encompass a 5 year complementary option.
- This contract gives us a major foothold in what looks like being one of the most promising markets this decade.

Kenya Central Water Treatment Facility

Conclusion

- Hydraulic fracking is an old but today questioned technology. Water preservation and environment protection are key for the social acceptance of shale gas field operation.
- When raw water is scarce, recycling and reinjecting flowback water reduce significantly withdrawals into rivers and lakes. Unconventional gas plays should be operated as much as possible with unconventional water resources!
- Clean exploration of shale gas is feasible, subjected that stringent regulation are established and appropriate means mobilized.
  - In May 2012, EIA defined golden rules for reducing nuisances and clean shale gas field operation. The cost of an effective environmental protection based on these rules amounts to 7% of production costs.
- Coal Seam Gas is considered to be one of the least carbon-emitting natural gases.
  - It can be converted to LNG, which can be transported over long distances safely and cost effectively by ship, making it possible to sell it worldwide.
  - With global demand for cleaner energy sources rapidly rising, the LNG market is about to boom.

Thank you for your attention