Water conservation and management at mining and oil and gas extraction sites

PECC, September 2017

Foreword (1):
Water, a sensitive raw material for oil and gas firms

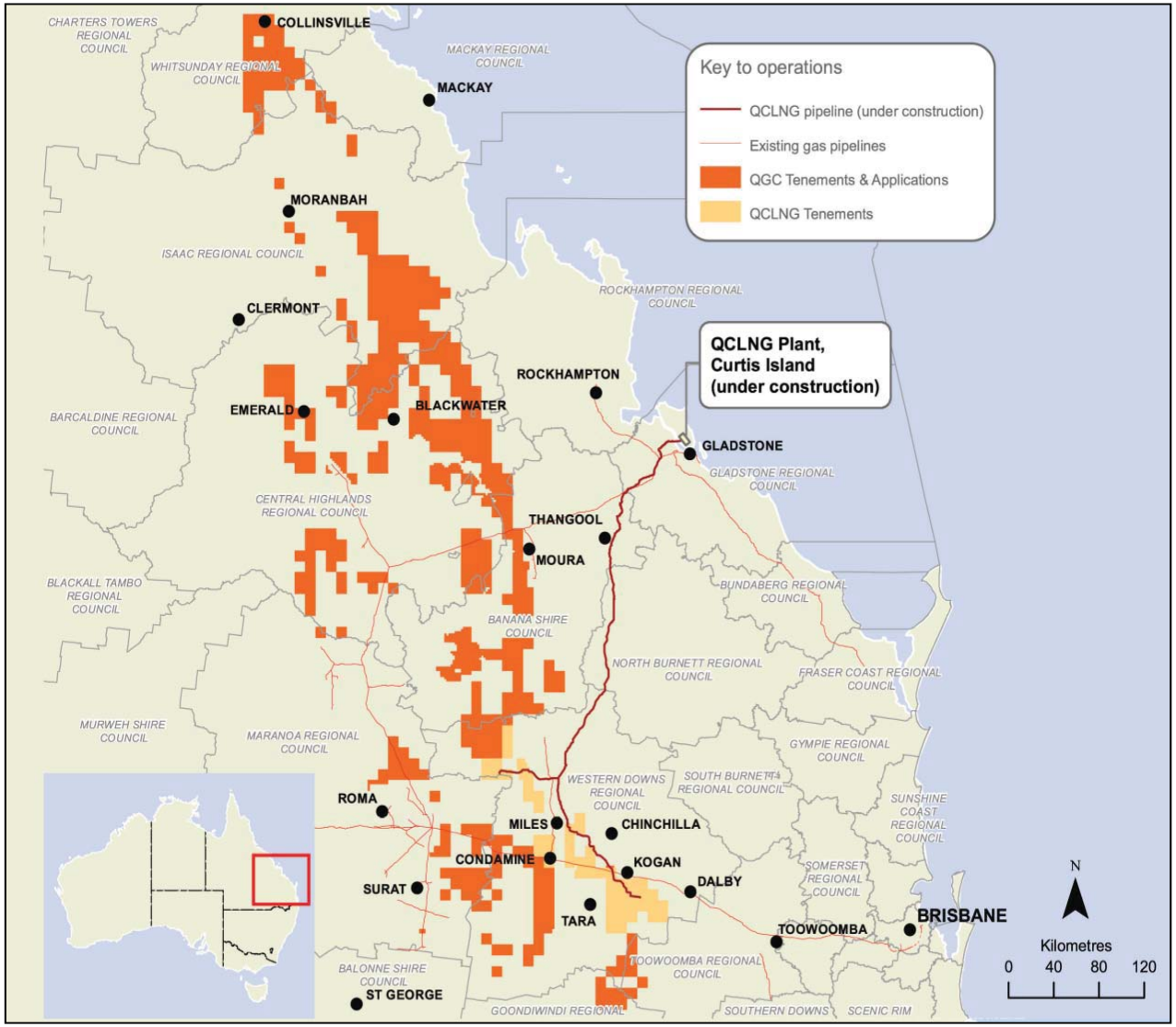
- **Oil and gas firms use more of water than any other fluid!**
  - *it takes 3 to 5 barrels of water to produce 1 barrel of oil, and up to 10 barrels for the most mature fields;*
  - *it takes 30 to 40 m3 of water to produce 1 m3 of unconventional gas!*
- **Water and energy are intimately bound up with each other.**
  - *You cannot produce energy without water—and vice versa.*
  - *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 mean of production.**

Foreword (2):
Veolia and hydrocarbons extracting activities

- 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 also one of the few companies proficient in all of the techniques required **to exploit shale oil and shale gas cleanly**, with no water pollution, and recycling all of the water used.
- **Veolia numbers the world's foremost oil and gas companies among its clients, including Shell, Total, BP, Chevron, Sinopec, Qatar Petroleum...**
- Veolia total turnover in oil and gas industry amounts to € 1.5 billion per year.

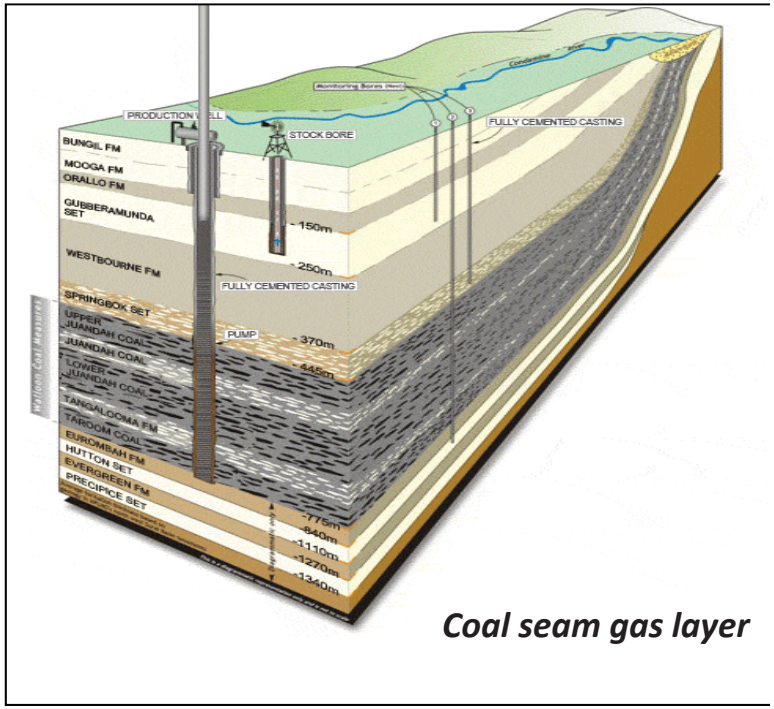
– Part I –
The Queensland coal seam gas contract



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),*
- *540 km of underground gas pipeline network to transport coal gas from Surat field to Curtis Island, where it is 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

- Field gas surface: 20,000 km2
- 6,000 wells to be drilled since 2030
- 3 water treatment plants operated (commissioned in 2013 and 2014)
- 200,000 m3 of water purified per day
- Contractor: QGC, leader in Australian natural gas exploration and subsidiary of BG Group (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
- Contract duration: 20 years + a 5 year complementary option.
- 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)

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 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*

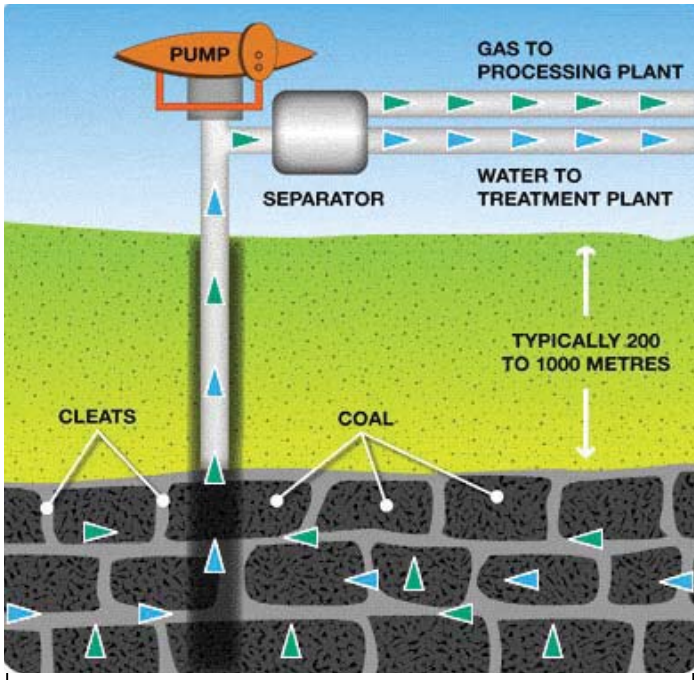


Diagram showing how coal seam gas and water are extracted

Environment,
a major concern everywhere

- **In neither Australia nor throughout the world, is it any longer possible to develop gas or oil fields without taking water issues extremely seriously.**
- Hydraulic fracking is an old but today questioned technology. Water preservation and environmental 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** (such as recycled wastewater)!
- **Clean exploration of shale gas is feasible, subjected that stringent regulation are established and appropriate means mobilized.**
  - *In 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.*

– Part II –
Reconciliating unconventional hydrocarbons extraction and water resource protection

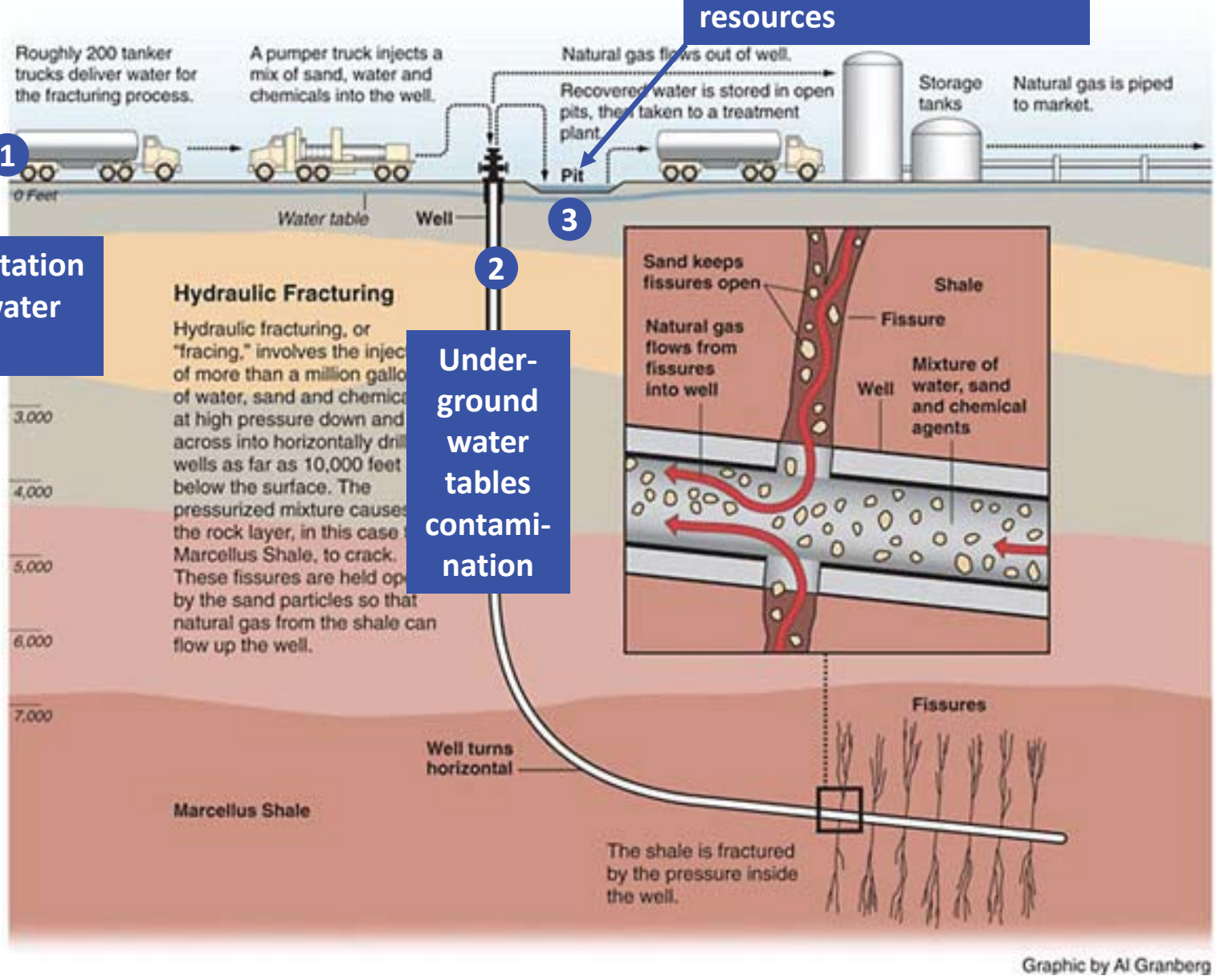
*Khazzan gas field, **Sultanate of Oman**, British Petroleum*

Impact points and risks to be controlled

Pollution of surface water resources

Overexploitation of scarce water resources

Under-ground water tables contami-nation



Graphic by Al Granberg

Water management issues

- **High water consumption:** 10,000 to 20,000 m3 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.**
  - *~ 2,500 chemical products 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

Water — 95%

+

Sand (proppant) — 4 to 4.5%

+

Chemicals — 0.5 to 1%

Solutions for a sustainable management of water during shale oil and shale gas extraction

There are various efficient technologies for depolluting wastewater

- *Removing specific salts (precipitation treatment, for instance Multiflo TM)*
- *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).

Criteria for treatment design:

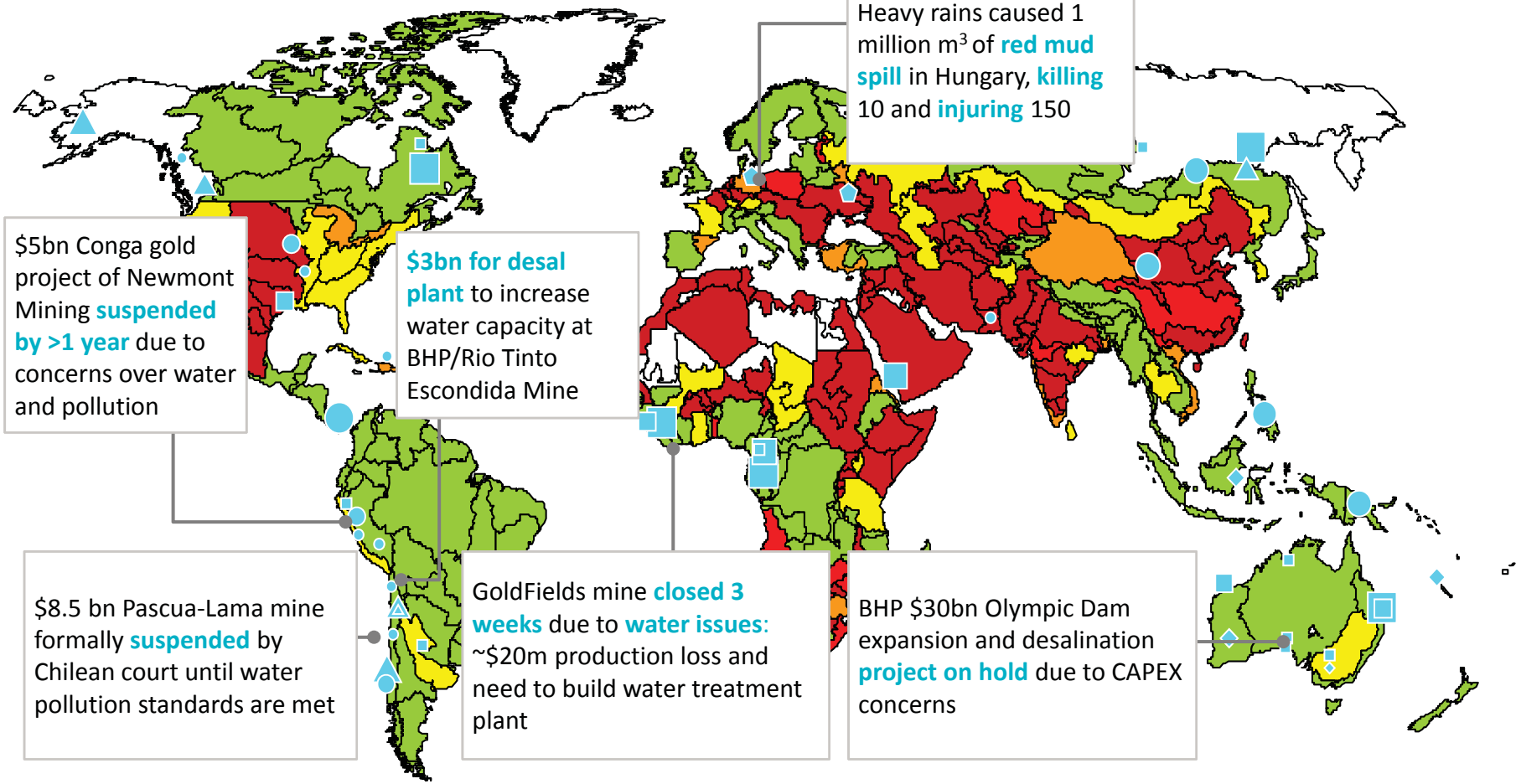
- *Water flows to be treated during normal and pick periods versus storage capacity*
- *Mobile, temporary or centralized water treatment units ?*
- *Logistics and energy scheme: on-site treatment versus transportation to a centralized unit*

Part III – Mining industry and water

Water, a major issue for the Mining industry

- **70 % of mining projects of the *Big Six* are located in water stressed areas**
- **At the world scale, the mining industry is the second largest water consumer (equivalent to the domestic consumption of the USA).**
- **Mines in arid regions rely heavily on groundwater of variable quality or even desalinated sea water.**
- **Possible conflicts in use with native population's access to water and with water-dependent ecosystems.**
- **Minimizing water footprint is key for gaining the environmental and social license to operate.**
- **Excess water provides challenges for environmentally compliant discharge**
- **Mining companies have targeted water usage reduction goals as key metrics of their business plans and competitiveness. It is both an issue of:**
  - *Cost management, as high use and scarcity drives up prices. (E.g. water costs from desalination as high as $5/m3 – equivalent to 5% of copper retail price)*
  - *Yield improvement through by-product recovery (E.g. 2-4% revenue increase for copper from tailings)*

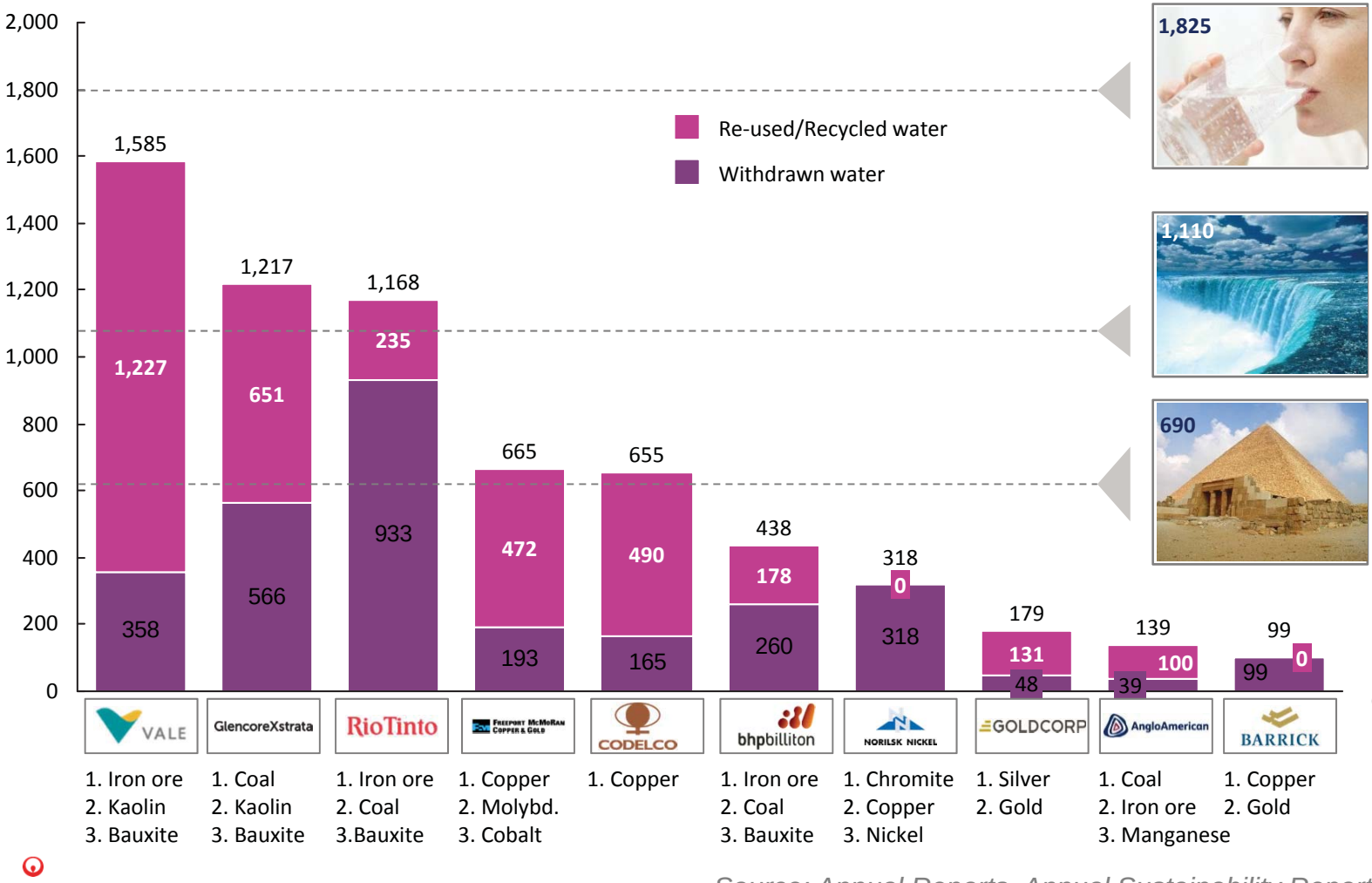
Water stress, increasingly a challenge for the Mining industry



Source: GrowingBlue.com; Press search, Team Analysis

While there is a wide dispersion in major mining players, even the least intensive use massive amounts of water!

Water use in million m³/year
(Sum of withdrawn freshwater and non-freshwater, including recycled/re-used water)



Equivalent to ....

Drinking water consumption of Eurozone citizens per month

Total water flow Niagara falls per week

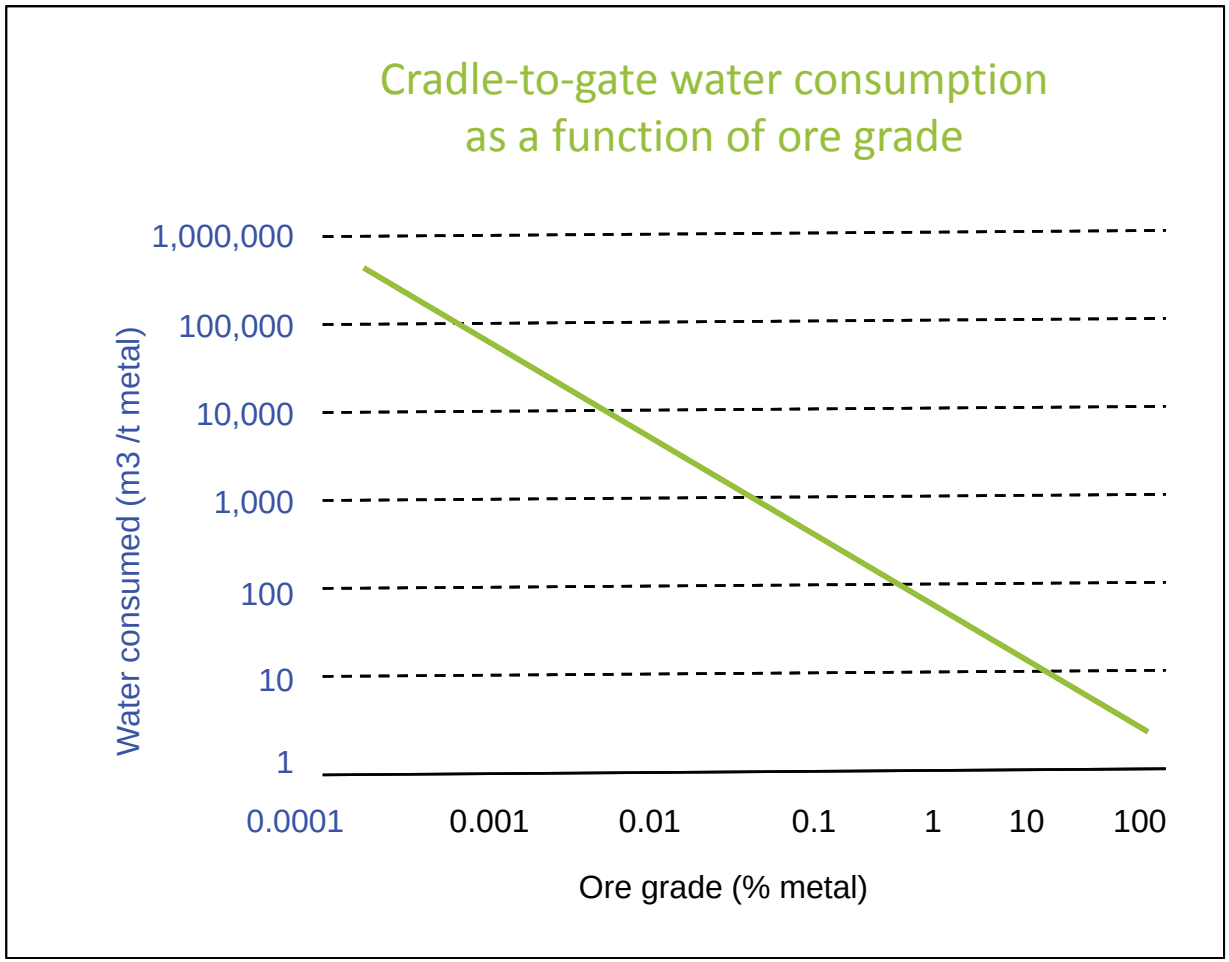
300x volume of Cheops Pyramid

Top commodities, ranked by tonnage

Source: Annual Reports, Annual Sustainability Reports, Team Analysis

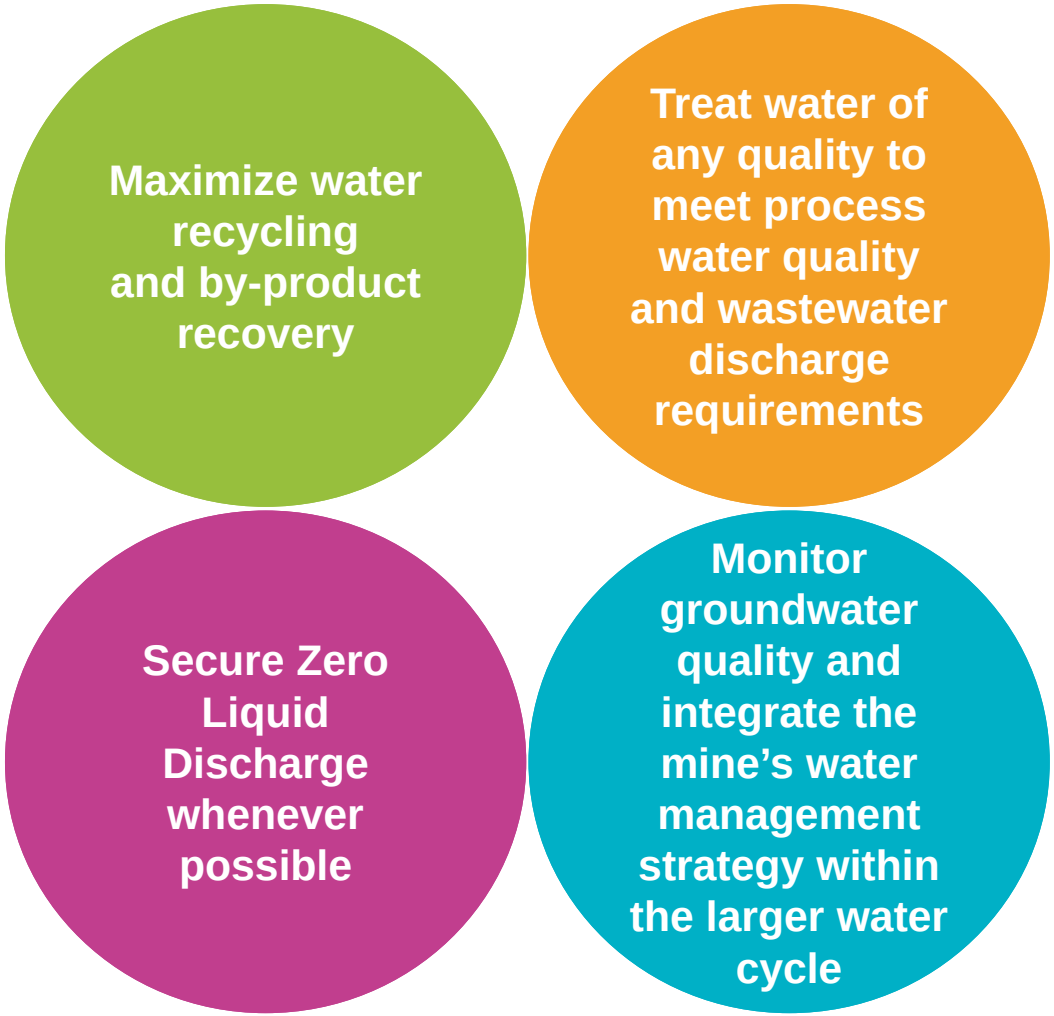
Mining, a high water consumption intensity

- **Withdrawal:**
  - *Water used for dust control, drilling and as slurry in product transportation*
- **Discharge:**
  - *Runoff and wastewater containing dust, sediments, metals and toxic chemicals*
  - *Drainage water from mines, that require treatment to discharge*



Source: CSIRO, Water use in metal production. A life cycle perspective, 2004

Creating a virtuous hydrocycle for mining industries

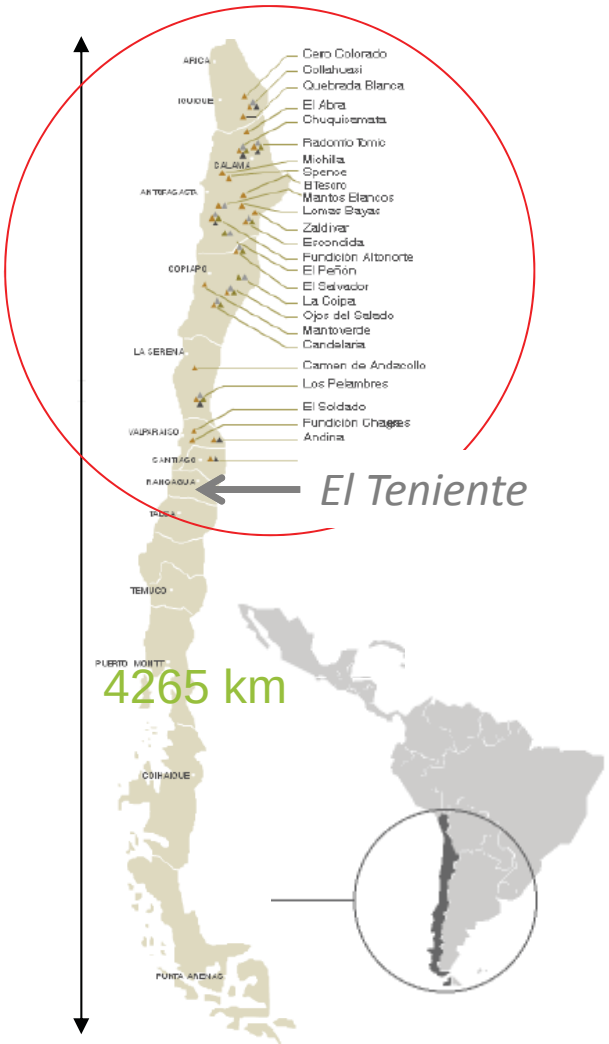


Veolia expertise

- *Dewatering*
- *Process water supply*
- *Water treatment*
- *Water discharge*
- *Water recycling*
- *Resource recovery*
- *Water remediation*

– Part IV –
The Codelco copper recovery contract

Chile, a mining country



Chile:

- *1st Cu producer (35%), > 29% Cu reserves*
- *1st Li producer (43%), 3rd Mo producer (15%)*
- *$100 billion to be invested by 2020 in mining*
- *Mining > 20% GDP*

Codelco = 2nd world largest Cu producer

- *Facing challenges*
  - *Increasing production costs (energy & labor)*
  - *Decreasing ore grade*
  - *Significant investment to maintain production*

El Teniente site:

- *Located 120 km south of Santiago de Chile*
- *The mine has been operating since 1905.*
- *The world's largest underground copper mine, producing 400,000 tons per year (23 % of Codelco's production)*

Codelco contract awarded to Veolia and its partner

Context

- *Codelco wanted to recover copper from tailings pond to reduce environmental liability and maximize copper extraction*
- *Dissolved Cu wasted in mining drainage*
- *Low concentrations does not allow direct recovery through traditional Solvent Extraction & Electrowinning process*

Solution proposed

- *Design, construction and operations of a copper recovery plant*
- *Treatment of 3 million cubic meters of water per year*
- *Multi-stage process to recover copper sulfates crystals for re-sale (CuSO4)*
- *Complementary treatment to remove contaminants (SO4, As, other metals…)*
- *Recovery of other metals such as Al, Zn, Co…*
- *Combination of concentration technologies including filtration and selective ion exchange for cost-effective recovery*

Contract

- *5-year DBOO contract*
- *Operation started at the end of 2013*
- *Toll fee per pound of Cu recovered*
- *Revenues: $8 million ; CAPEX: $5 million*
- *Minimum recovery rate to be reached: 80% of inlet, product [Cu] > 3 ppm*

Process overview, to recover dissolved copper from tailings pond water

Barahona Tailings pond drainages

Influent
100 – 400 ppm Cu

10% Sulfuric acid solution
Copper extraction

Industrial water
Resin washing

Sand filters
TSS removal

Activated carbon filters
Oil & grease removal

Ion Exchange columns

Filtered water without copper

Tailings canal

Copper sulfate concentrated solution (to SX plant)

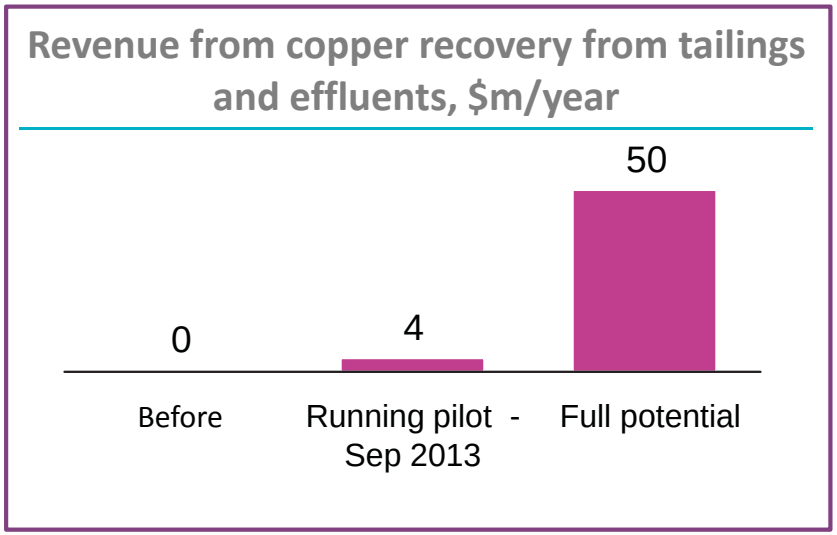
Discarded solution from washing

Caren Tailings pond

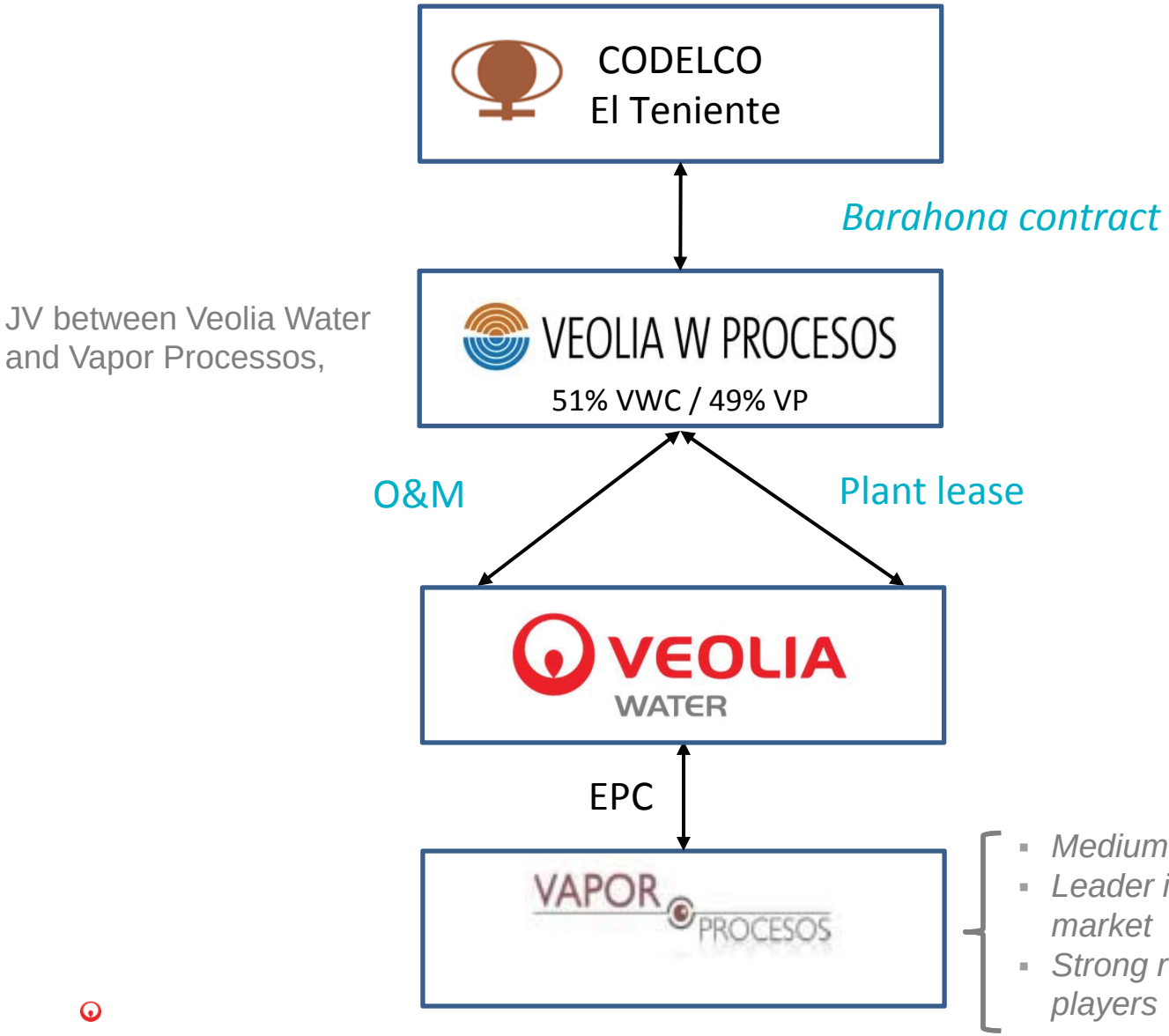
Metallic Copper

How did this solution help the mining company?

- **It converted a potential closure liability into an additional copper revenue stream of $2-4m for pilot.**
  - *Calculation based on recovered copper price at 60% of market price of $ 7100 / ton, and current pilot production at ~500 tons / year.*
- **The potential to expand capacity allows to reach 3% copper output increase (12,000 tons p.a.) or $50m revenue from additional residual copper sources.**
- **The result is the production of CuSO4, which is less sensitive to Cu market price variations.**
- **Transportation cost by third party can be reduced by increasing Cu concentration.**



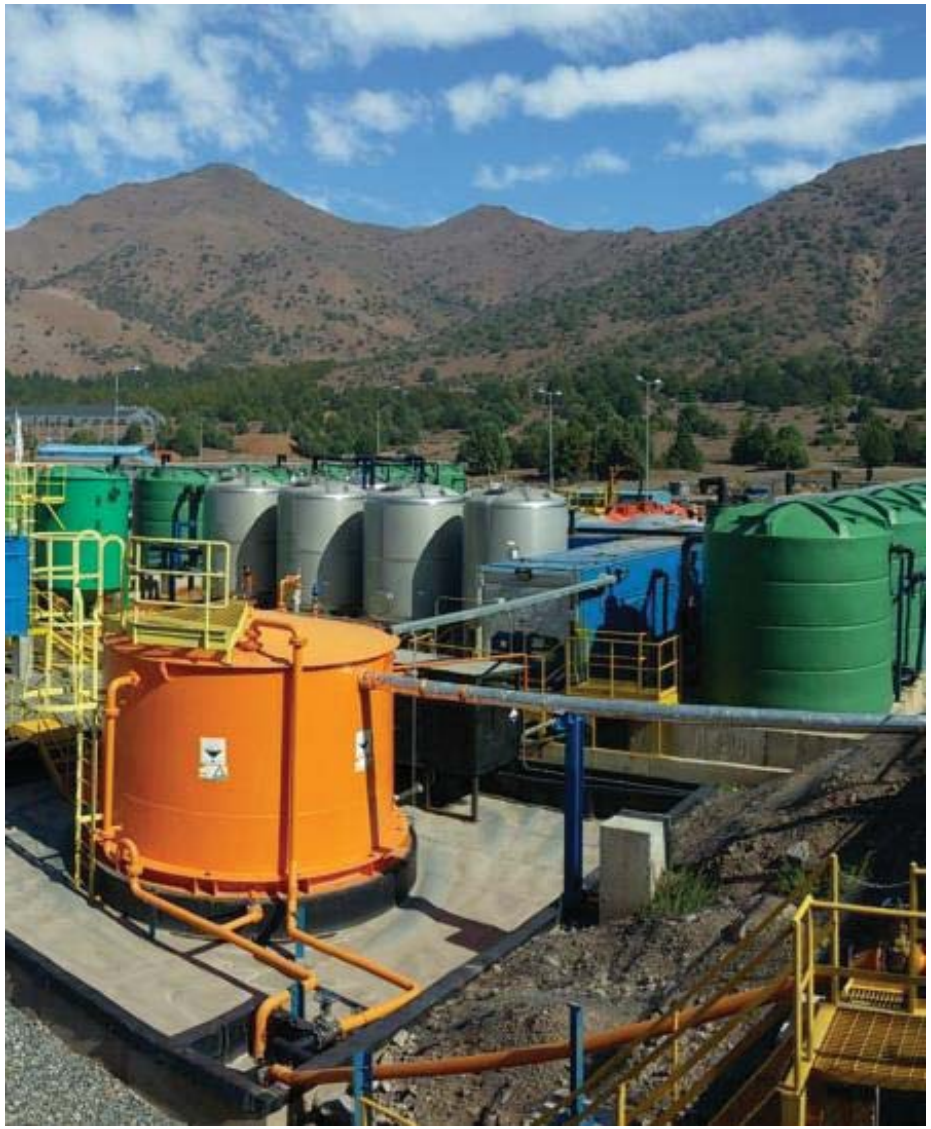
Project structure:
a cooperation between Veolia and Vapor Processos



- *Medium size Chilean company*
- *Leader in the Chilean copper recovery market*
- *Strong relationship with key mining players*

The benefits for the mining company

- Optimize production cost: the extra copper is recovered from tailings at a cost lower than extraction.
- Boost the total mine production, with cost-efficient copper recovery.
- Lower the environmental impact, by removing copper elements from tailings drainage.
- Improve the environmental image of the mine, as a more sustainable mine site.



Conclusion

Obtaining licences to operate, a growing challenge which heavily depends on water management

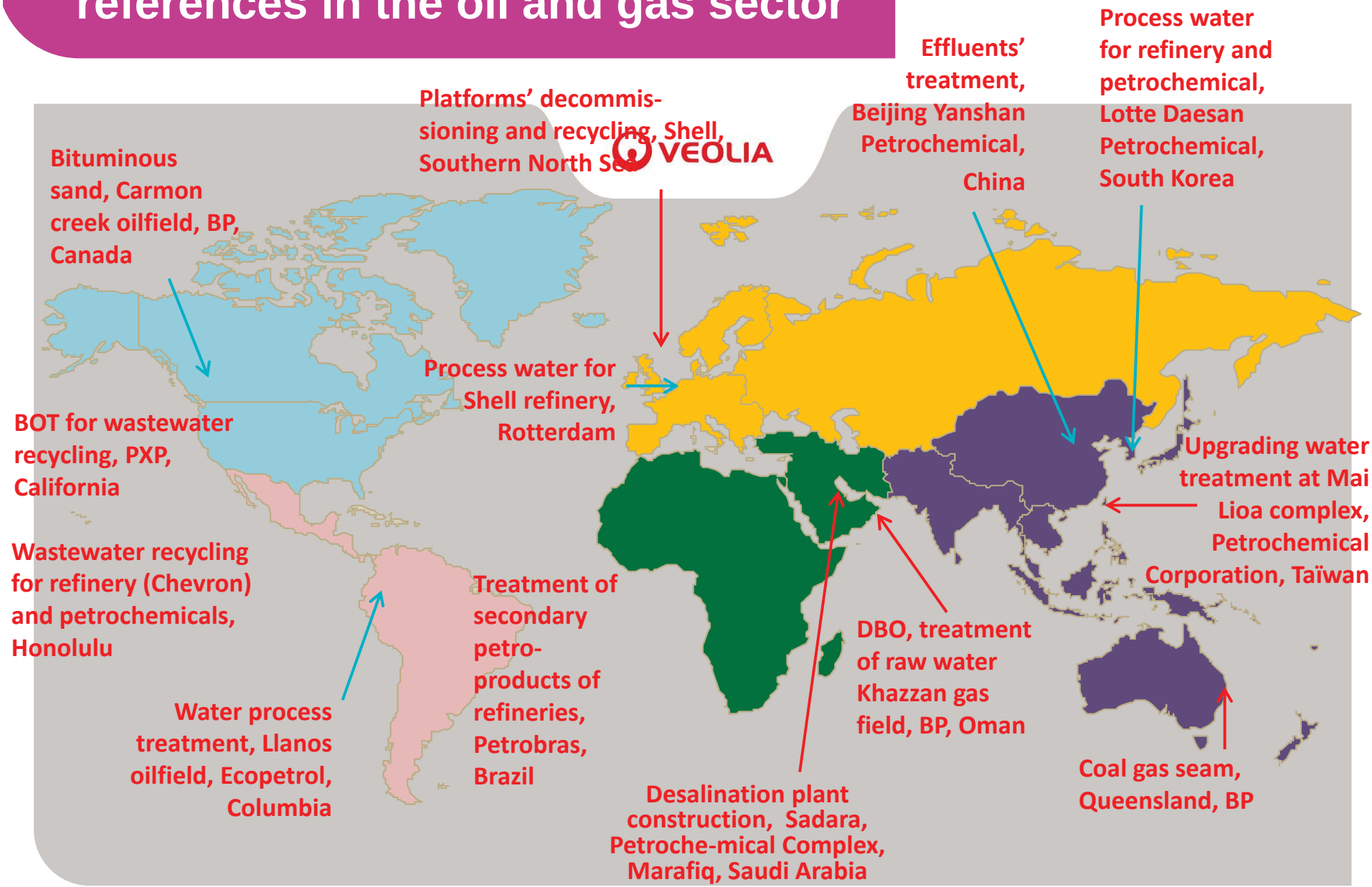
- Extracting companies are subject to heavy political and regulatory pressures.
- Licenses to operate mines and oil and gas fields can only be obtained, subjected to compliance with very strict environmental constraints.
- Water-saving targets are among the key parameters, not only of their business plans, but also for the renewal of their exploitation licenses.
- Consequently, a perfect environmental management is a sine qua non for the mining industry, if it is to maintain its activities and open additional mines.

The evolution of Veolia relationship with extracting companies

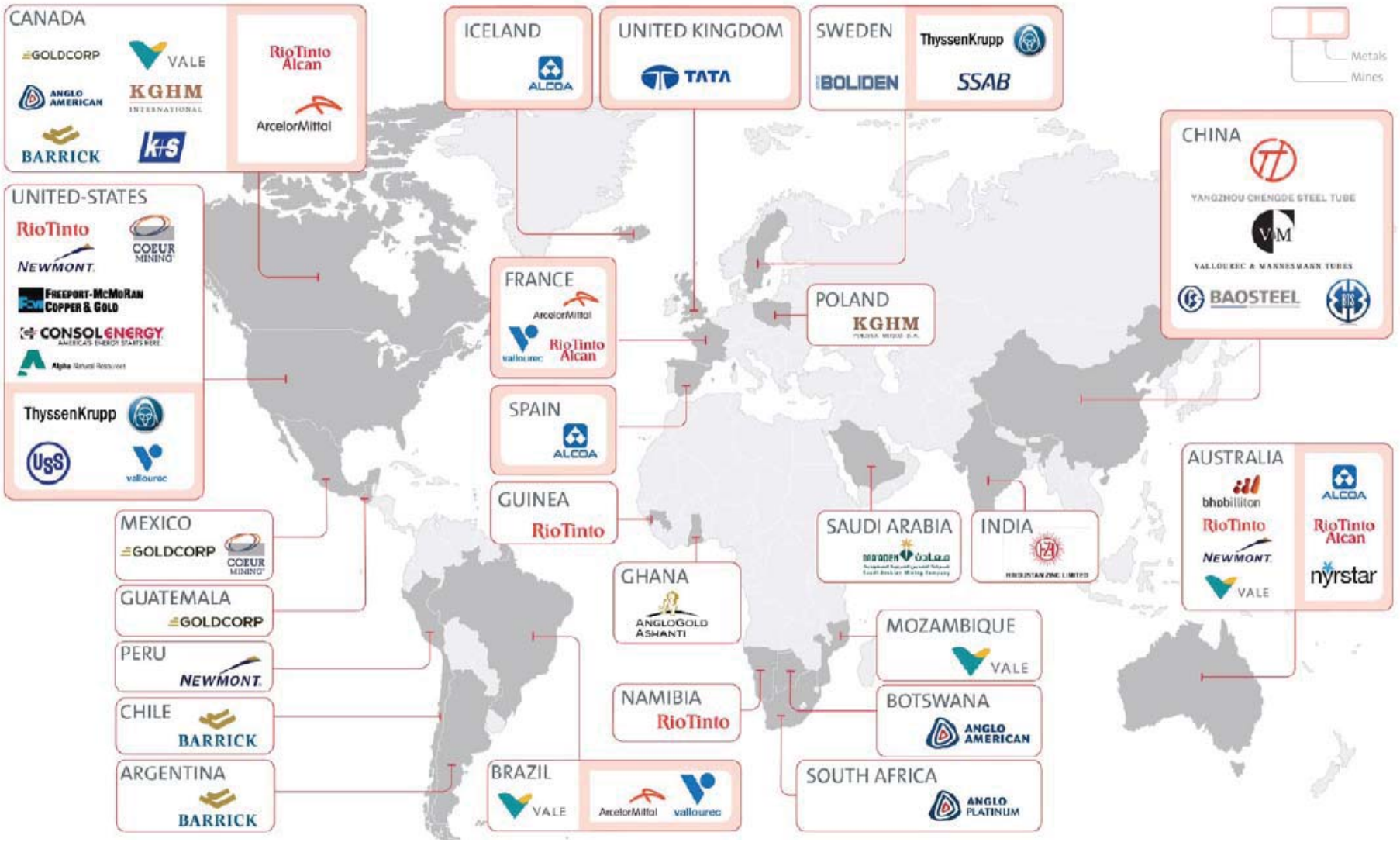
- The issue is no longer just a question of helping extracting firms to protect the environment and comply with regulations; it is also a question of helping them to compete economically, by optimizing water and wastewater management within their processes.
- Previously, our role for companies in this sector was as a technical supplier that they might ask to resolve a particular problem. Now, we work alongside them as a genuine partner in their development, improving their productivity and profitability.
- This link between economic and environmental performance is the foundation of our collaboration with extracting companies.

Thank you for your attention

Foreword (3): A few Veolia references in the oil and gas sector



Veolia, a leading partner of Mining & Metals companies



- Veolia customers include the world's main companies in this sector: Anglo American, BHP Billiton, Barrick, Rio Tinto, Vale, Goldcorp, Alcoa, Baosteel…

Some drivers impacting water consumption in mining facilities

Mining and processing methods:
- Mining: surface or undergroung mining
- Proecessing: varies with ore type and grade

Geology of the site and commodity type
- Geology: hard rock, sulfur, coal, sand or gravel
- Ore: type and grade (in general, lower grade ores require more water to process)

Nature of operation:
Scale and type of processes operated at the mine site

Power generation:
On site or importing from off site, particularly regarding steam

Local regulatory constraints:
More or less stringent discharge requirements, depending wether water is considered as a valued resource or as a nuisance requiring management and disposal

Climate of the site:
- Dry climate: potential conflict use
- Humid climate: potential pollution of the environment by rainwater

Source: USGS, National Handbookof Recommended Methods for Water Data acquisition