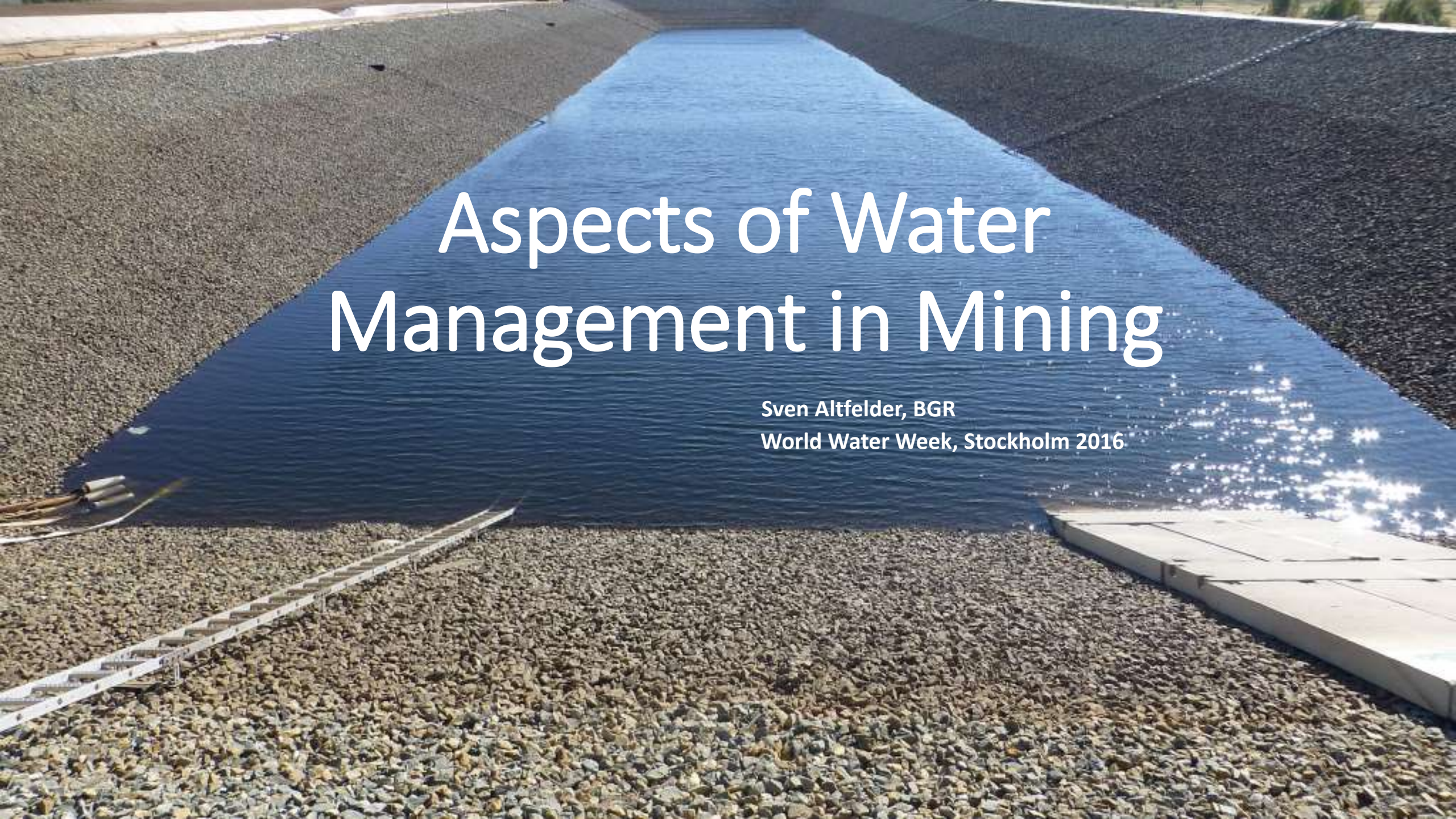
Presentation from

2016 World Water Week in Stockholm

www.worldwaterweek.org



Aspects of Water Management in Mining

Sven Altfelder, BGR

World Water Week, Stockholm 2016

Outline:

1) Water as a resource in mine development

2) Water management in mine operation

3) Water management in post mining

Ethiopian (Danakhil) Potash Project, Afar

- Hottest place on Earth, Ethiopia's north-eastern Danakhil depression
- Desert area with elevations as low as 50m to 128m below sea level
- Surrounded by the Danakil Alps. (1,000m elevation)

Source: Fugro GmbH

Main features:

- Area of approximately 150 square kilometres.
- 1,000m series of evaporite - high rates of subsidence
- Drilling program began in 2010.
- 588.2 million tons of inferred potash mineral resources (estimate of June 2012)

Source: http://investorintel.com/wp-content/uploads/2013/10/apatyl2.jpg

Ethiopian (Danakhil) Potash Project, Afar

- Groundwater research in preparation for solution mining - part of a bankable feasibility study
- Open pit not feasible due to insurmountable problems

- Preconditions for mining/solid investment decision is the stable/sustainable supply of relatively fresh water.
- Water is scarce in one of the hottest areas on Earth - no rainfall for most of the year.

- Border zone between the highland and depression consists of tertiary to quaternary alluvial fan sediments.
- Unconsolidated, they interfinger and lie above the Pleistocene and Holocene sediments of the depression → potential sources for processing water?

Source: https://www.caesarsreport.com/tag/allana-potash/

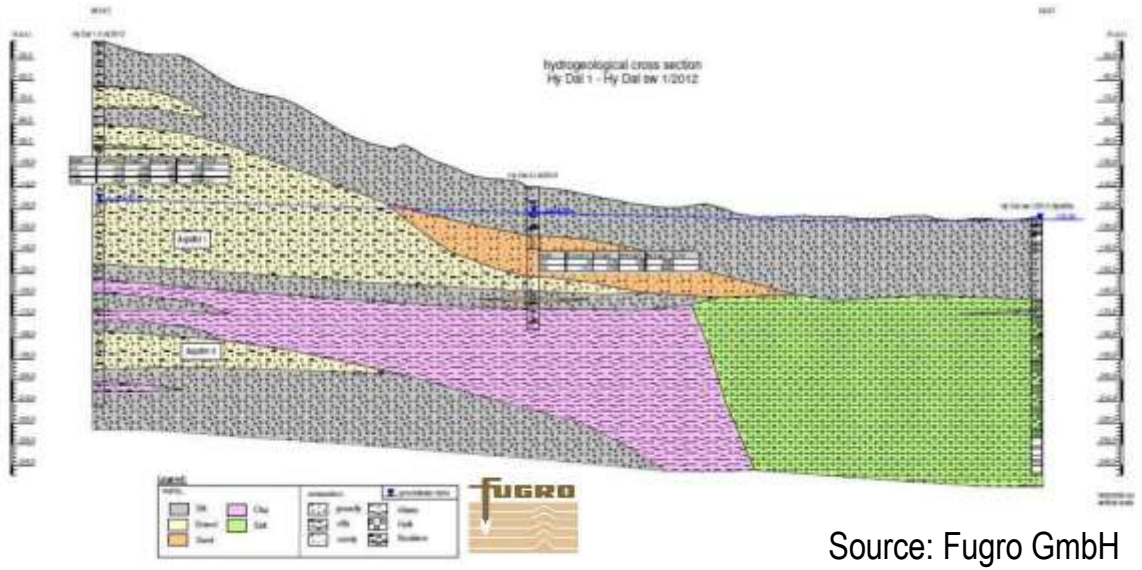
Source: http://imgur.com/gallery/9xXTBbf

Water as a resource in mine development

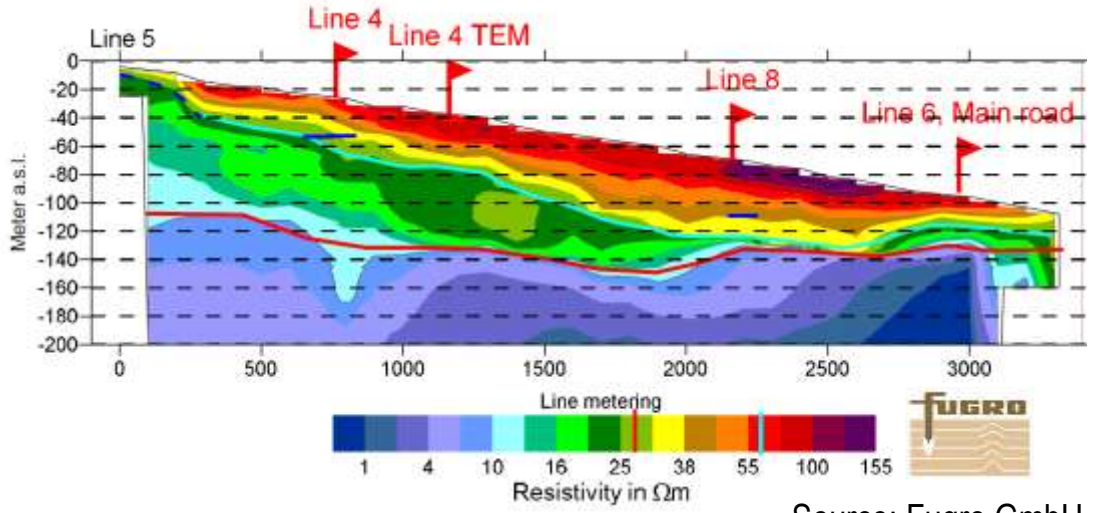
Ethiopian (Danakhil) Potash Project, Afar

- Alluvial fan sediments have a surprising amount of (fresh) water.
- Source are the nearby Ethiopian Highlands rising up to 3,000 metres.
- Water transported via wadis and fault structures - stored in the fans beside the salt flats.
- Pump tests and water analysis showed that water is suitable for solution mining of potash salts.
- Groundwater recharge is sufficient to cover at least 3 million m^3 yearly from one alluvial fan
- Enough for mining operations over the next 20 to 25 years.

→ Two weeks ago Israel Chemicals closed the project because of potash long term prospects .



Source: Fugro GmbH



Source: Fugro GmbH

Water as a resource in mine development

Mongolian Copper Mine, Oyu Tolgoi

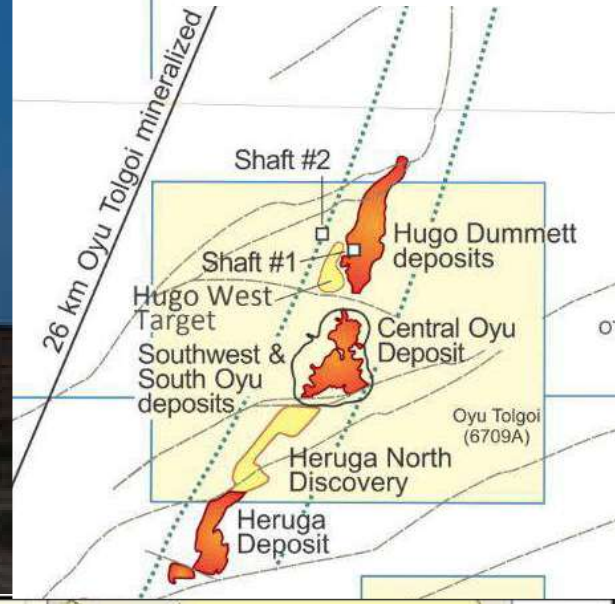
- South Gobi Desert, one of the driest areas of Mongolia
- 80 kilometres (50 mi) north of its border with the People's Republic of China

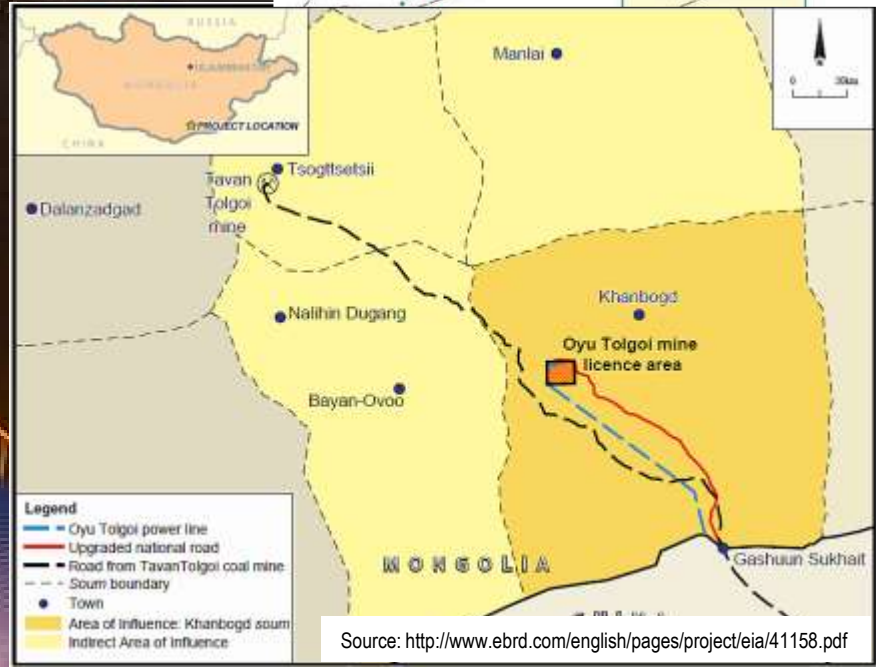
Main features:

- Deposits cover an area of 84.96 square kilometres.
- 25 km of mineralisation along a NNE aligned trend down to a depth of more than 1500 m
- Drilling program began around 2000.
- Contains an estimated 2,700,000 tonnes of copper.
- Production began in 2013 (full capacity) in 2021.
- Over >50 years 430,000 tonnes (470,000 short tons) of copper per year,
- Equal to 3% of global production

Source: http://www.riotinto.com/ourcommitment/features-2932_17328.aspx

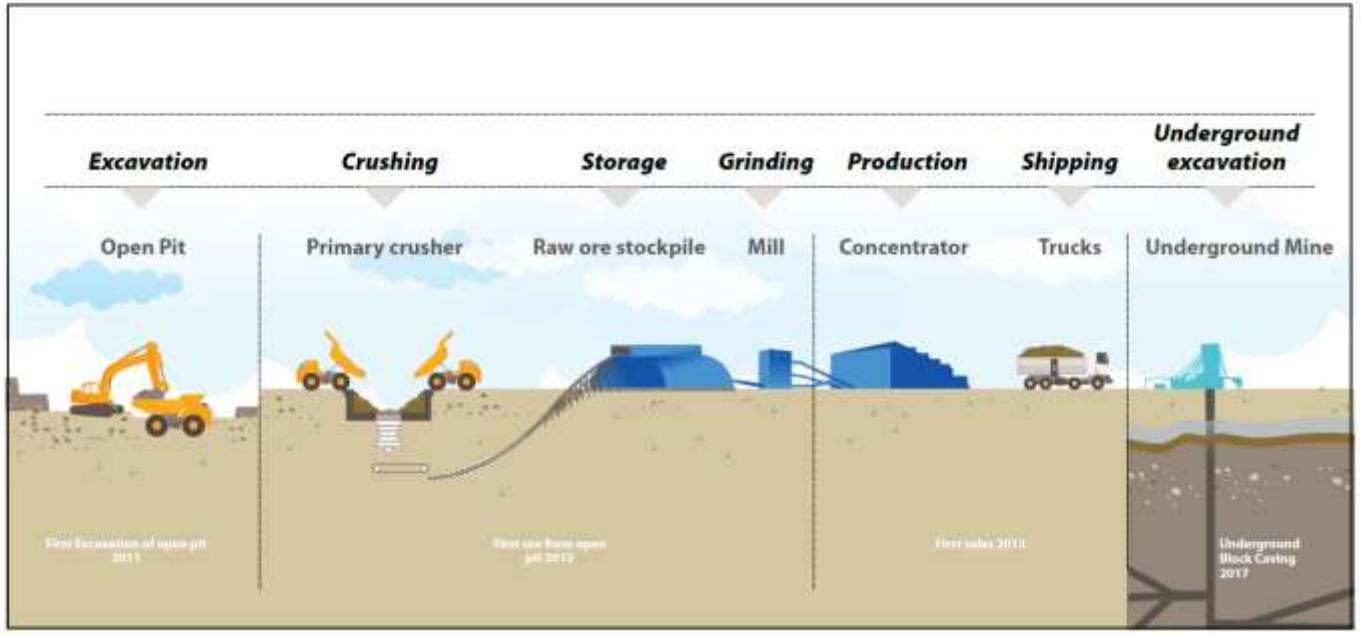
Source: http://www.turquoisehill.com/i/pdf/2014-10-27_OyuTolgoiTechReport.pdf





Source: http://www.ebrd.com/english/pages/project/eia/41158.pdf

Mongolian Copper Mine, Oyu Tolgoi



Source: http://www.ebrd.com/english/pages/project/eia/41158.pdf

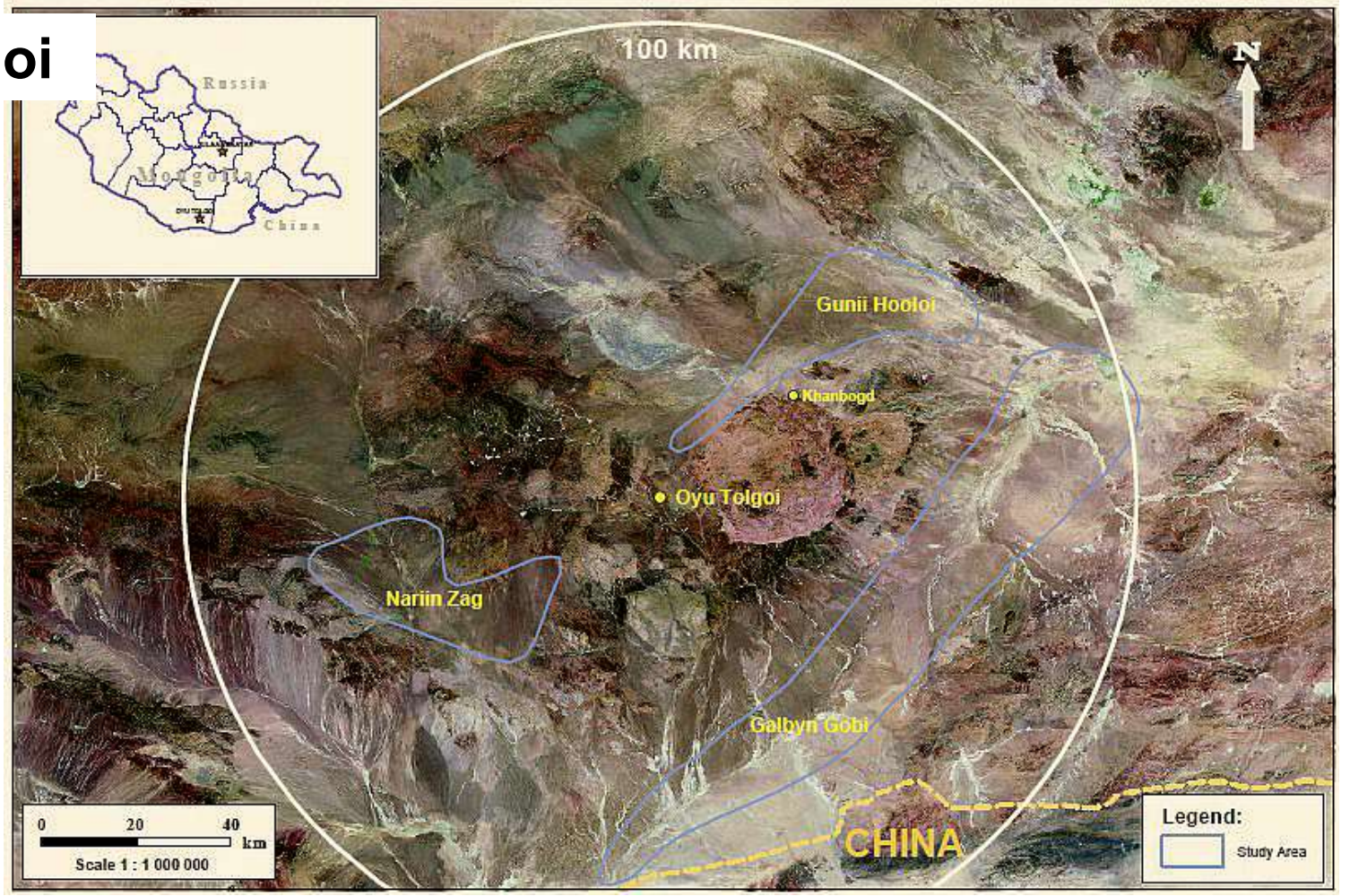
- No refining or smelting in onsite operations
- Gravitational separation process producing concentrate
- Most water required by the concentrator (prod. of saleable product)

- 520 litres of water to process one tonne of ore → less than half the global average amount of water consumed by similar mines.
- Water is scarce in the South Gobi region - annual precipitation is just 80 mm. 90% during storm events in the warm summer season.

- A potential water source immediately available are the deep, typically more saline, fossil aquifers in the region - assumed to be beyond the reach of local herders (due to their depth).

Mongolian Copper Mine, Oyu Tolgoi

- Premise to balance the needs of an operational mine and the current and future populations
- Groundwater investigation in three cretaceous basins - Galbyn Gobi, Gunii Hooloi and Nariin Zag
- Substantial groundwater resources identified in the Galbyn Gobi and Gunii Hooloi basins.
- Only Gunii Hooloi aquifer has sufficient reserves to supply the water demand → and remain a significant future reserve for further abstraction by Oyu Tolgoi or others.



Source: http://ifcext.ifc.org/ifcext/spiwebsite1.nsf/0/D8A67E4647784ED385257A62005D32E1/$File/B6.pdf

- More than 150-400 metres below surface it is assumed to be far to deep to affect the shallow groundwater from springs and wells used by local herders
- A 70km pipeline has just been completed to deliver that water.

Mongolian Copper Mine, Oyu Tolgoi

- The Government has permitted to use 20 per cent of the aquifer's 6.8 billion m^3 capacity,
- Sufficient to supply the company's current water needs for more than 40 years (870l/s).
- The water left is big enough to supply Ulaanbaatar, for the same period of time.

- Most water-conservative mine in the world:
  - Recycling 100 per cent of domestic waste water, and 80 per cent of processing water.
  - Water management procedures are recovering of groundwater that surfaces when ore is removed in the open-pit mine. High-efficiency thickeners are being used to reclaim water from tailings.
  - A floating cover is installed on the lagoon that holds water piped from the aquifer preventing evaporation.

Mongolian Copper Mine, Oyu Tolgoi

- It is reported that Gunii Hooloi boreholes (with one exception) do not intersect shallow aquifers which are not present over large parts of the deep aquifer
- Gunii Hooloi area is commonly referred to as ‘camel pasture’ reflecting the lack of available water
- Levels and quality of water in herders’ hand-dug wells monitored since 2003.
- Since 2011, herders have been making their own records for comparison
- The data has not demonstrated negative impact on the wells due to the project.

Water controversy on Oyu Tolgoi:

- Citizens feel they are being ignored
- Company officials feel their work to support independent review groups at Oyu Tolgoi is not appreciated.
- Dwindling water supply is viewed by stakeholders as chronic problem that hasn't been addressed to the extent that residents feel their complaints produce actual results.

"Without resolution of these issues, feelings of marginalization and exclusion will continue to cause local, regional, and national tensions about Oyu Tolgoi and mining development in general.

However, mining has had the positive effect of politicizing citizens, who are now more aware of and active in local politics.

The mine is a big target. They do get picked on more than other companies. But at the same time, if they are pushed that raises standards. And they are being pushed."

Source: http://www.circleofblue.org/2013/world/mongolia-copper-mine-oyu-tolgoi-tests-water-supply-young-democracy/

Mount Polley mine, B. C., Canada, 4. Aug.2014

- Open pit copper and gold mine (with an underground component)
- Commenced operations in 1997
- Area of 19,601 hectares
- Water abundant – but apparently too abundant…….

3D View Looking Northeast

Source: http://globalnews.ca/news/1490361/tailings-pond-breach-at-mount-polley-mine-near-likely-bc/

Mount Polley disaster (10 Mio. m^3 water / 4.5 Mio. m3 slurry), B. C., Canada, 4. Aug.2014

- Shear failure of dam foundation materials (glacial till)
- Increased loading imposed by the growing dam
- Failure occurred rapidly and without precursors

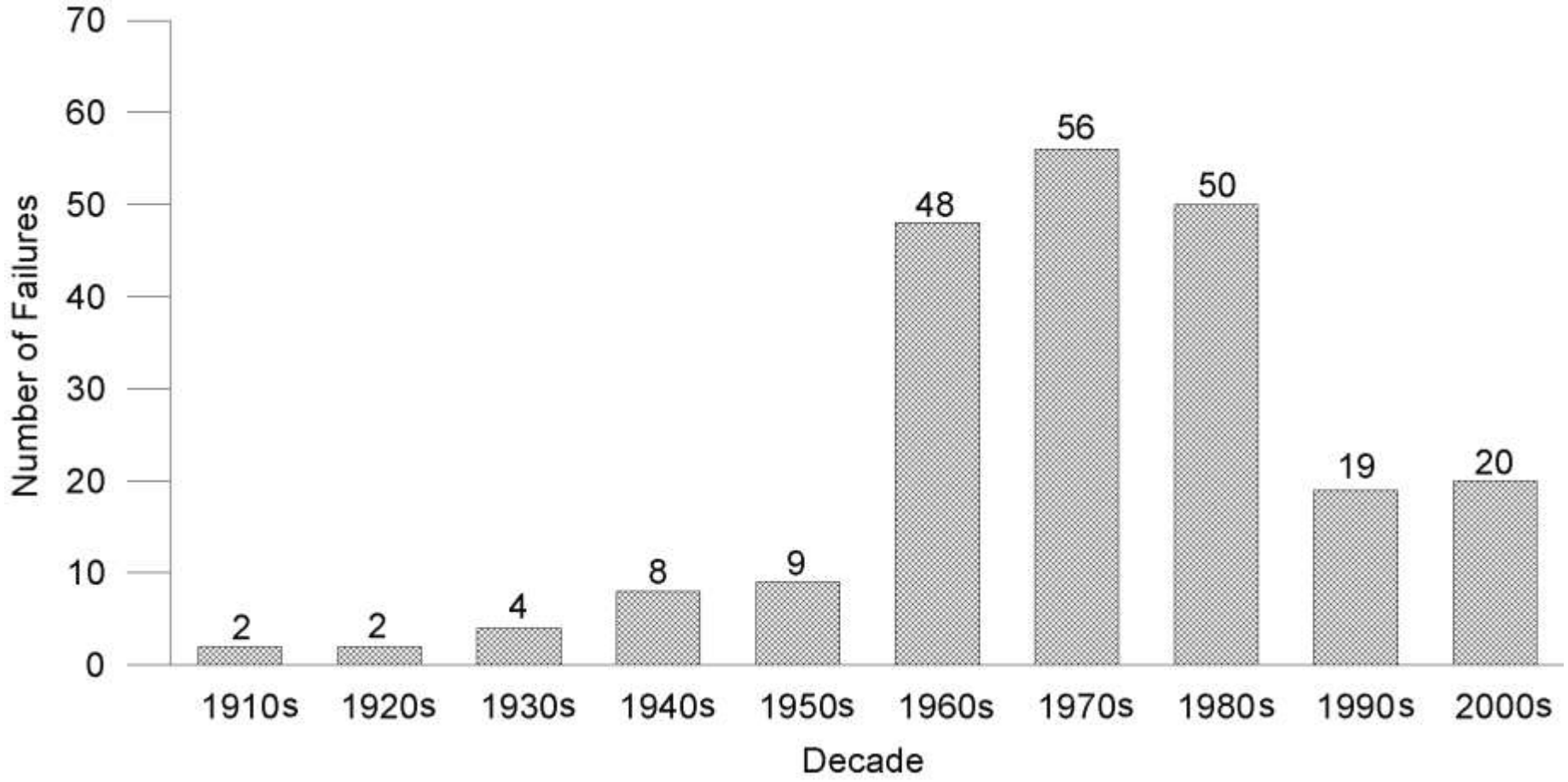
- Dam raising proceeded incrementally, one year at a time.
- More reactive than anticipatory,
- No long-term planning or execution.

- Absence of an adequate water management or water treatment strategy
- Absence of a well-developed tailings beach (fundamental of the design as a tailings dam)

Source: http://commonsensecanadian.ca/mount-polley-spill-may-far-bigger-initially-revealed/

Water management in mine operation

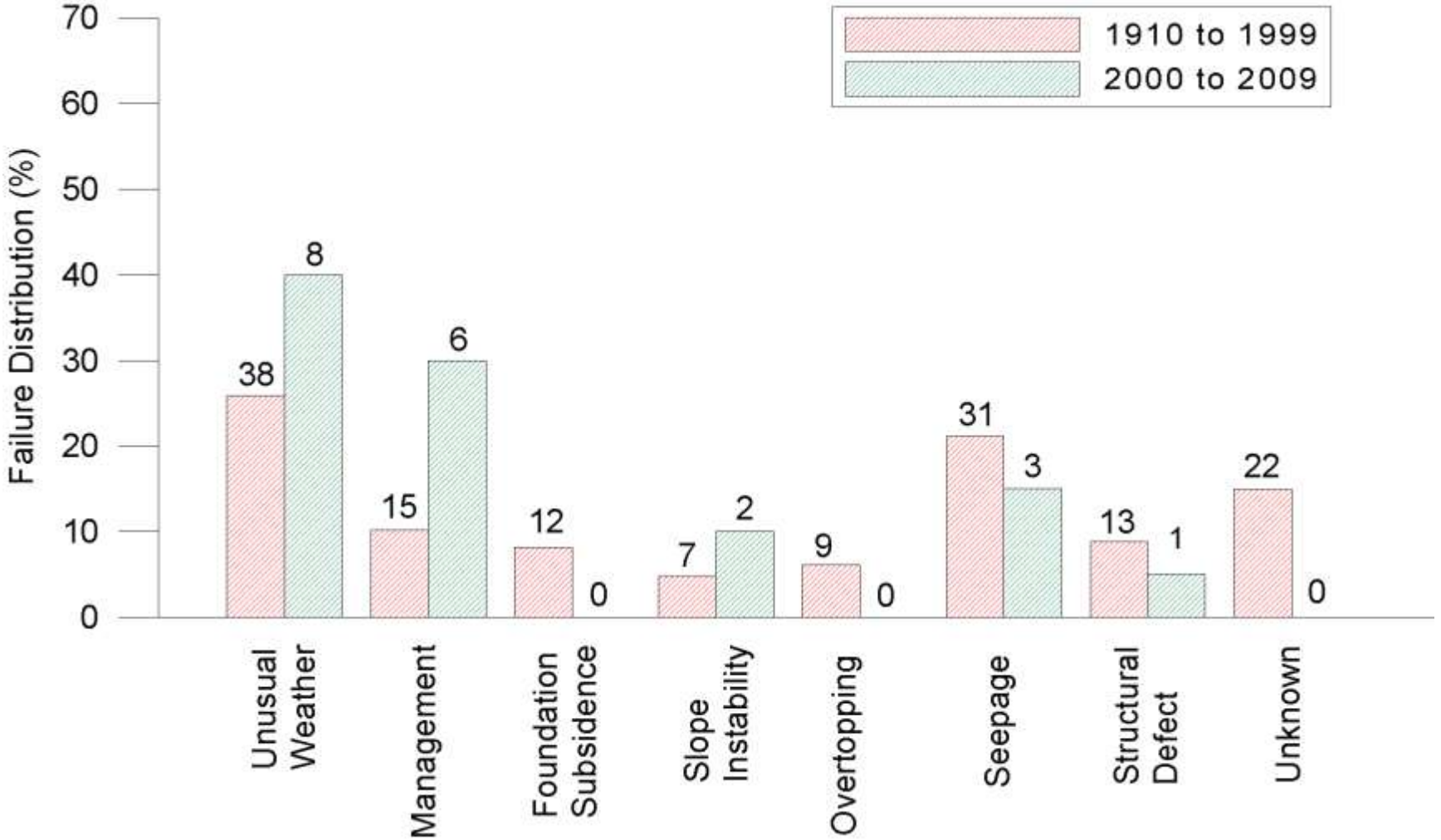
Major recent disaster: Failure of the Bento Rodrigues dam (release of 60 million m3 of slurry), Mariana, Brazil 5 November 2015 – investgation ongoing……



"For a world inventory of 18401 mine sites, the failure rate over the last one hundred years is estimated to be 1.2%"

Source: Azam, Li – "Tailings Dam Failures –
A review of the last 100 years"
Geotechnical News – December 2010

How often does poor water management play a role in tailings dam failures?



Source: Azam, Li – "Tailings Dam Failures –
A review of the last 100 years"
Geotechnical News – December 2010

Wismut, Germany - Uranium mining legacy tailing pond – when things don't go wrong……..

Source: Wismut GmbH

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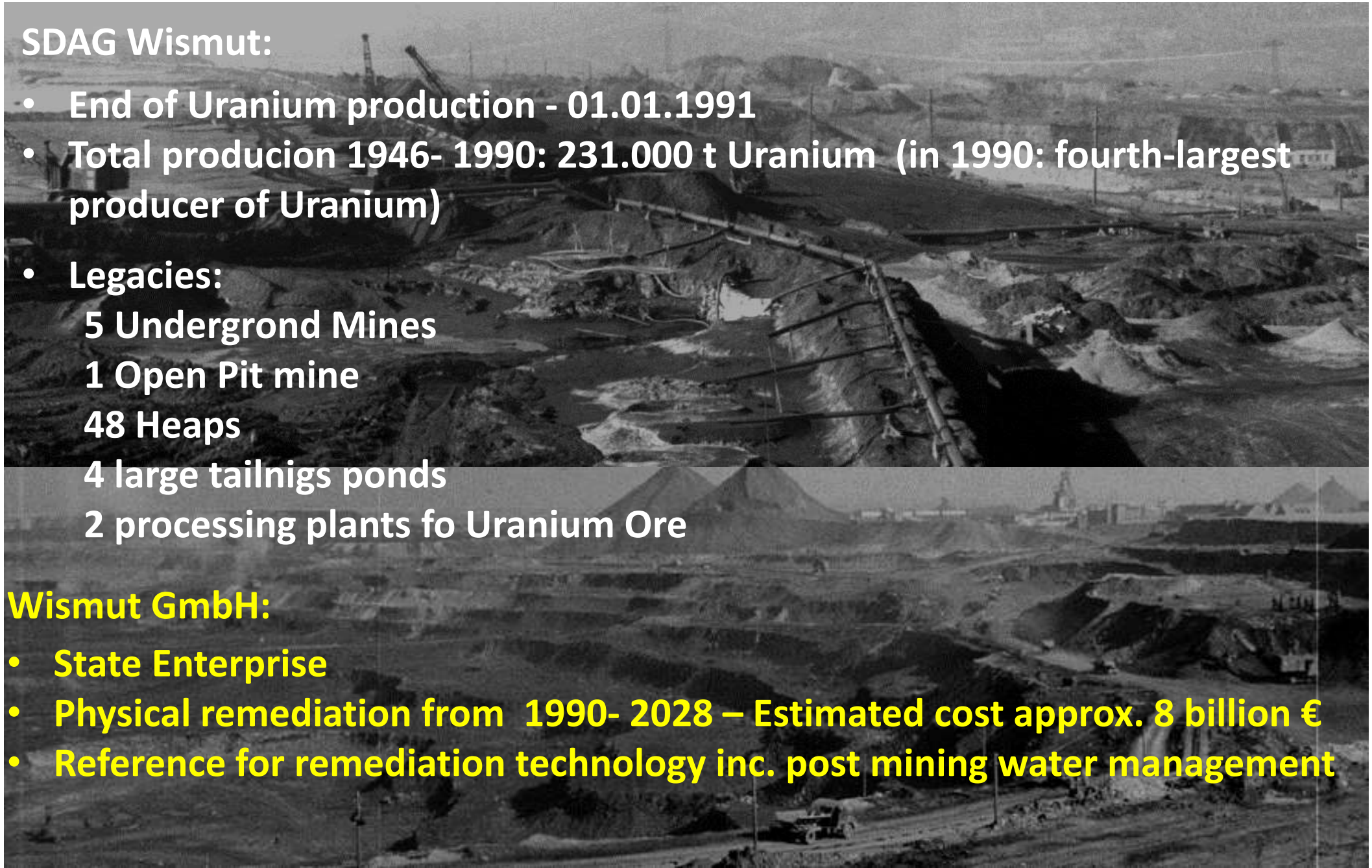
- **Embankment stable according to GDR-design**
- **Longterm embankment stability questioned in the early 90ties (no acute risk - even though level of unreleasable contaminated water increased in the early nineties).**
- **Immediate measures:**
  - **Water treatment plant,**
  - **Removal of uncontaminated surfacewaters,**
  - **Release of untreated seepage water, operation of drainage wells,**
  - **Building an upstream protecting embankment.**

Water management in post mining



SDAG Wismut:

- End of Uranium production - 01.01.1991
- Total producion 1946- 1990: 231.000 t Uranium (in 1990: fourth-largest producer of Uranium)
- Legacies:
  - 5 Undergrond Mines
  - 1 Open Pit mine
  - 48 Heaps
  - 4 large tailnigs ponds
  - 2 processing plants fo Uranium Ore

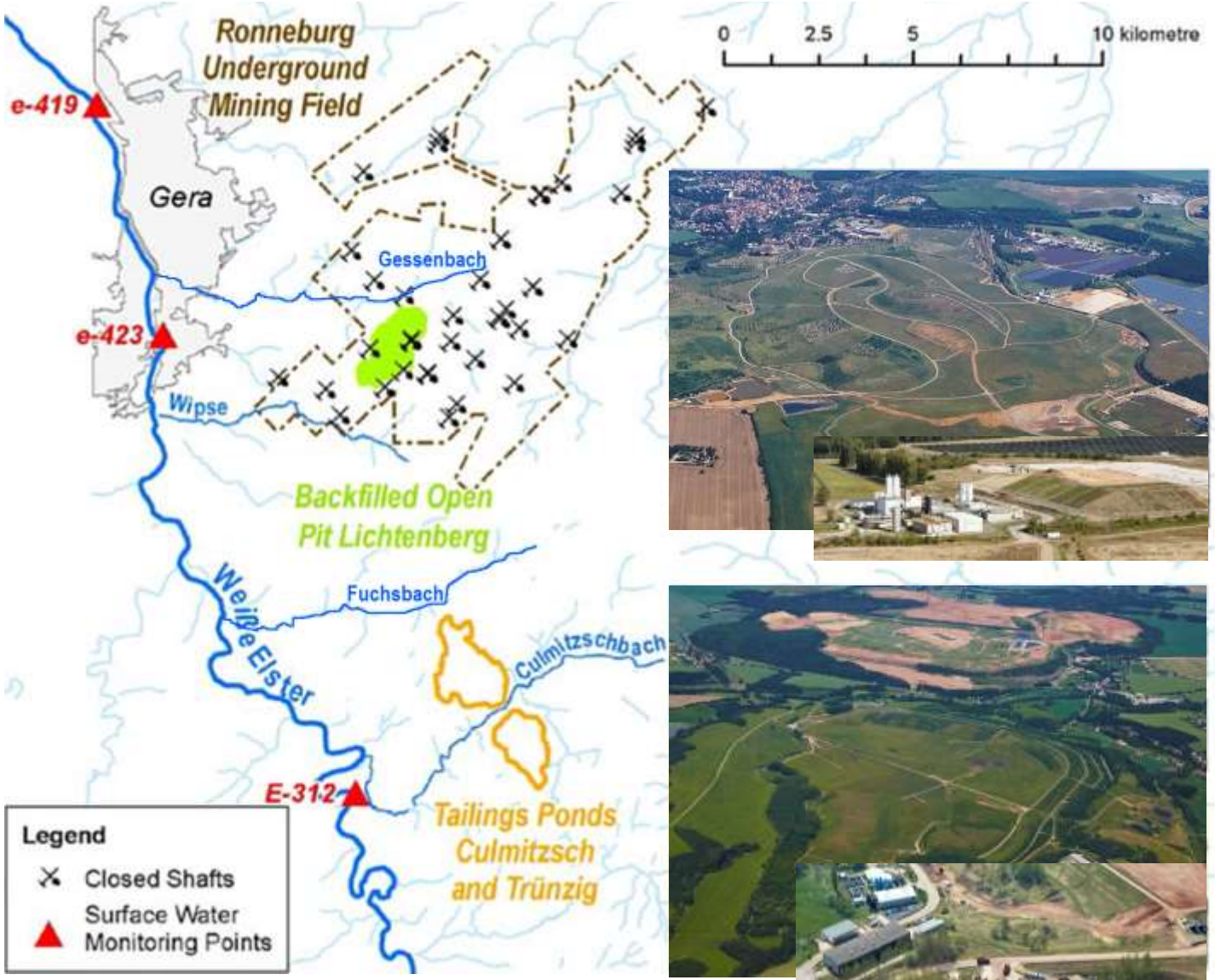
Wismut GmbH:

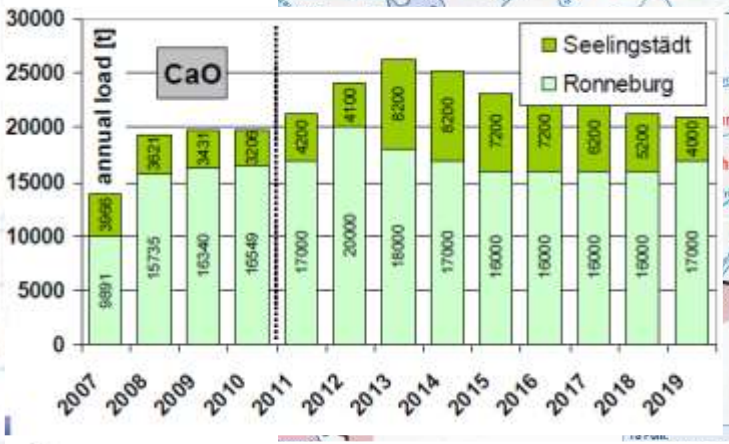
- State Enterprise
- Physical remediation from 1990- 2028 – Estimated cost approx. 8 billion €
- Reference for remediation technology inc. post mining water management

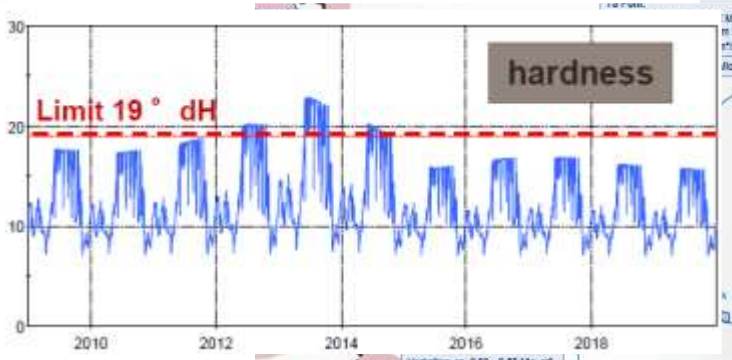
Water management in post mining

Water and load balances from Uranium Mining legacies of Wismut GmbH

– Salt-concentration and hardness in Weiße Elster river







Source: Wismut GmbH

Some conclusions:

- Water magement decisions in mining are driven by economic pressure
- Aspecs of water management in mining are getting more attention today (but still not enough)
- A strong regulator is needed to push proper water management by the mine operator
- Proper mine water management should not be a privilege of the rich
- Water has a price tag – it should reflect in commodity prices