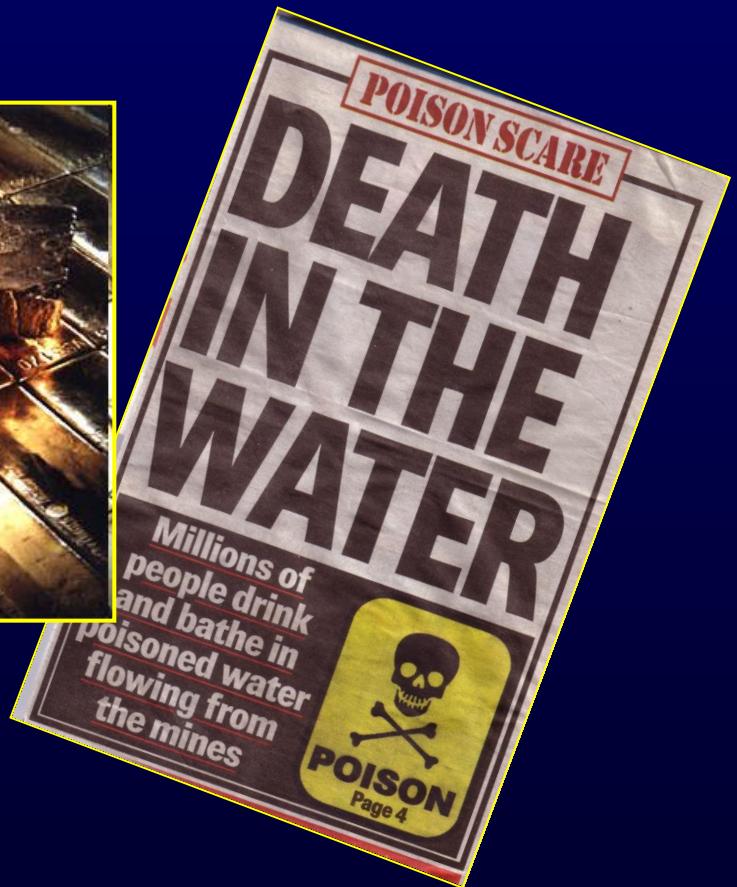
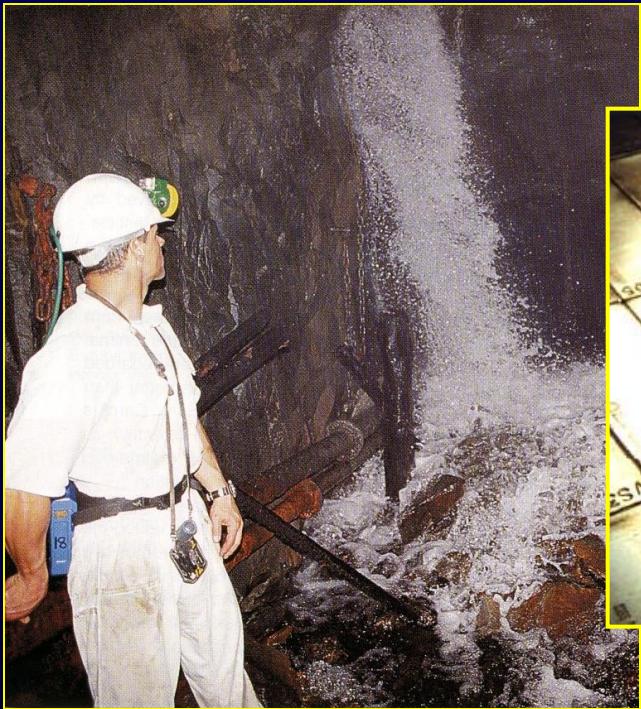


31 August – 1 September 2011; Emperor's Palace, Kempton Park, Johannesburg (South Africa)

## BLUE vs. TRUE GOLD

### Impacts of deep level gold mining on water resources in South Africa – insights from selected case studies



Frank Winde

NWU Potchefstroom Campus  
Mine Water Research Group



NORTH-WEST UNIVERSITY  
YUNIBESITI YA BOKONE-BOPHIRIMA  
NOORDWES-UNIVERSITEIT



## (1) Introduction

## (2) Au mining impacts on water resources: 3 x case studies

(A) *Dewatering of karst aquifers*

(B) *Uranium pollution*

(C) *Flooding of mine voids (AMD decant)*

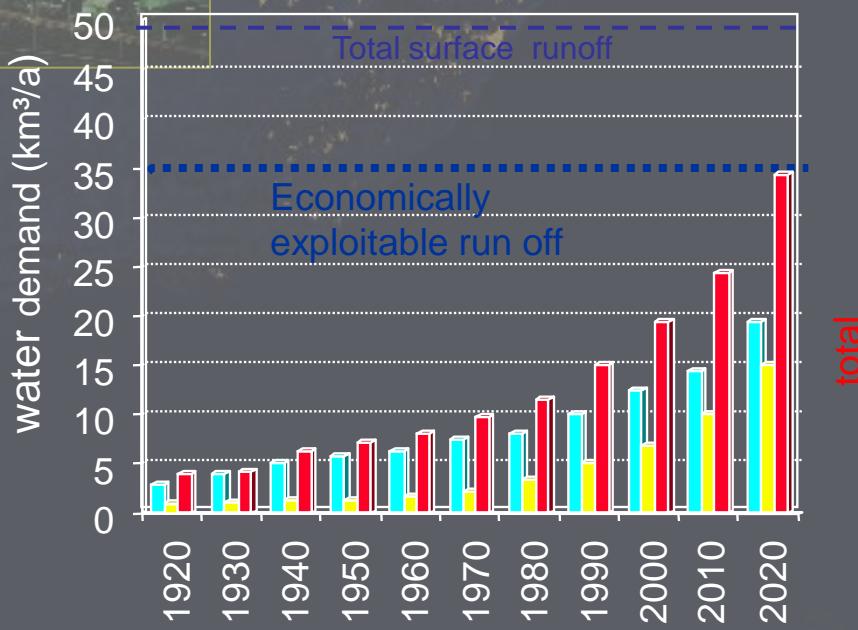
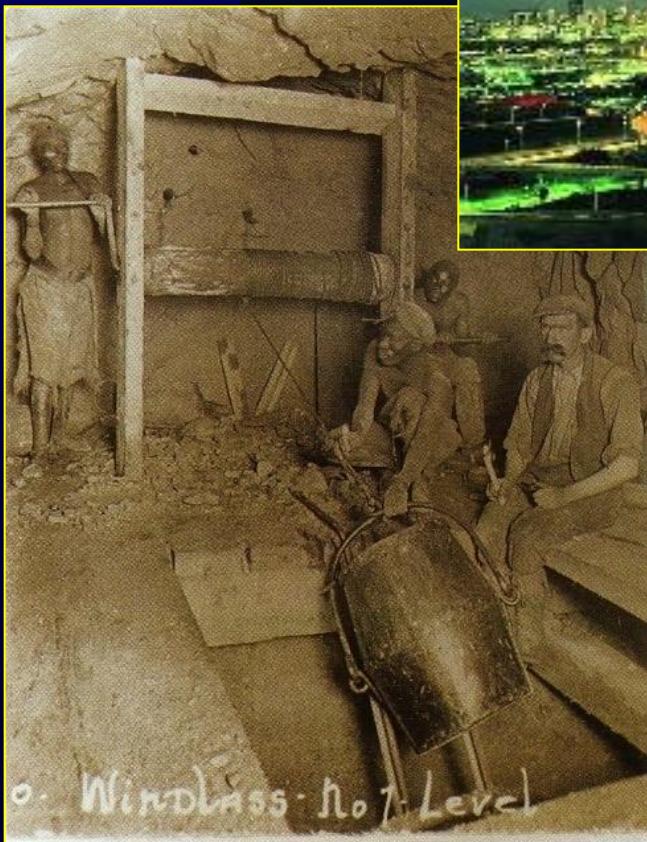
## (3) The future?



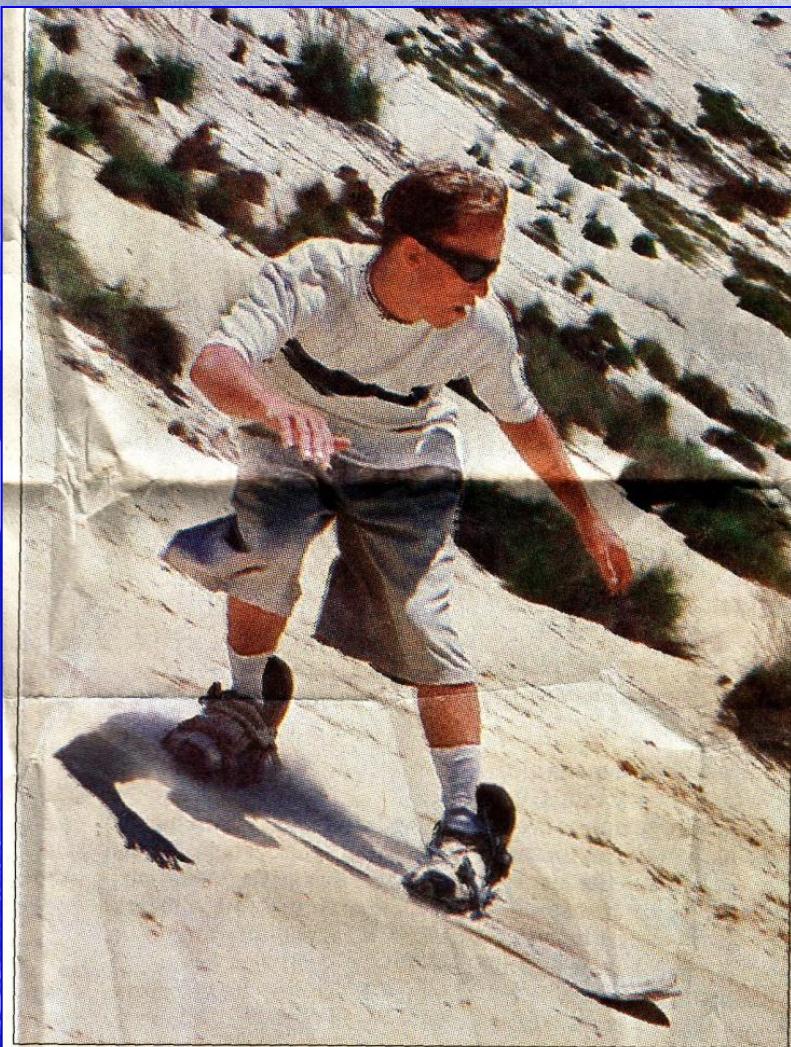
## Largest urban agglomeration in Africa:

- triggered by Au rush 125 years ago, today:
  - 25% population SA
  - 50% of energy consumption in Africa
  - 70% GDP SA
  - 70 km from nearest major river: strongly negative water balance → imports from Lesotho

125  
a



**125 years of Au production:**  
>>6 bn t of tailings covering ~400 km<sup>2</sup>



Gathering speed ... Jon Geall (19) takes a fun run down 'Mount Mayhem', a mine dump outside Boksburg.

The Star .... Wednesday April 11 2001

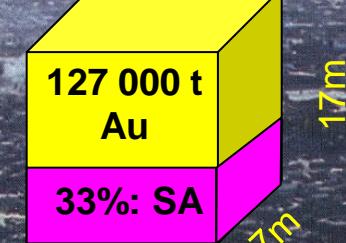
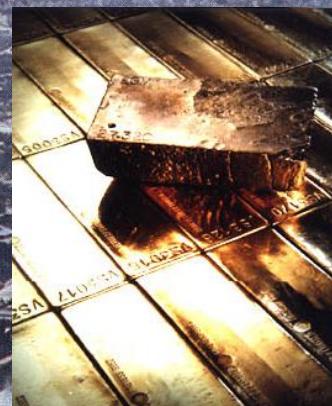
*In the absence of snow, daredevils do it on dusty mine heaps, writes John Murphy*

## 'Dumpboarding' is new extreme sport

Total since 1886: **42,000 t**

1970: Peak of SA gold production (**989 t**)  
= 68% of world production

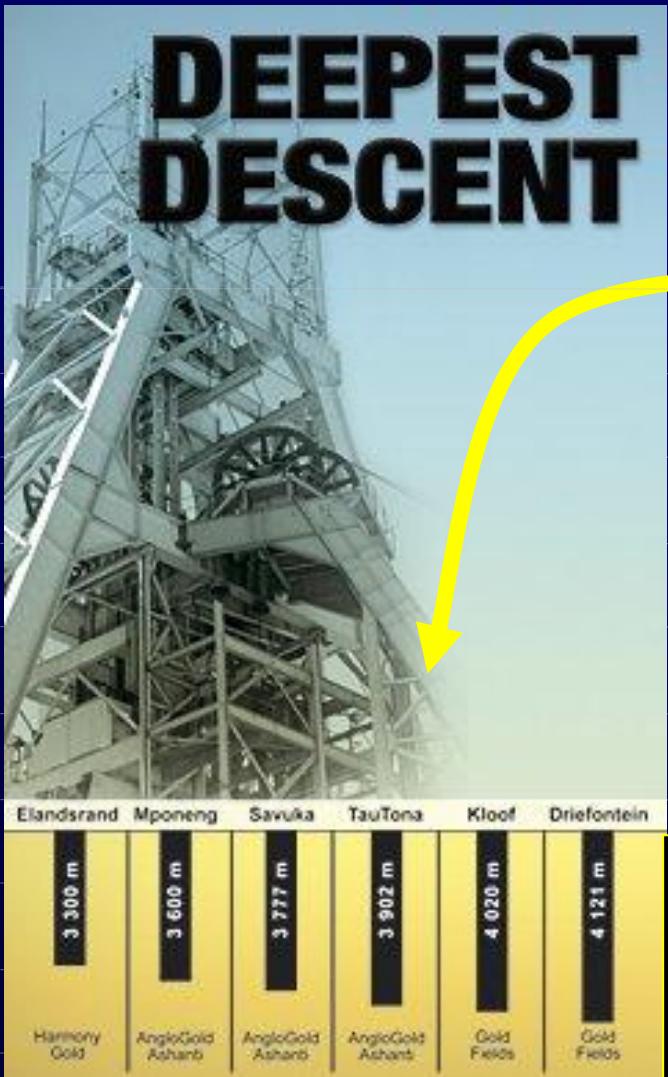
all gold ever poured:



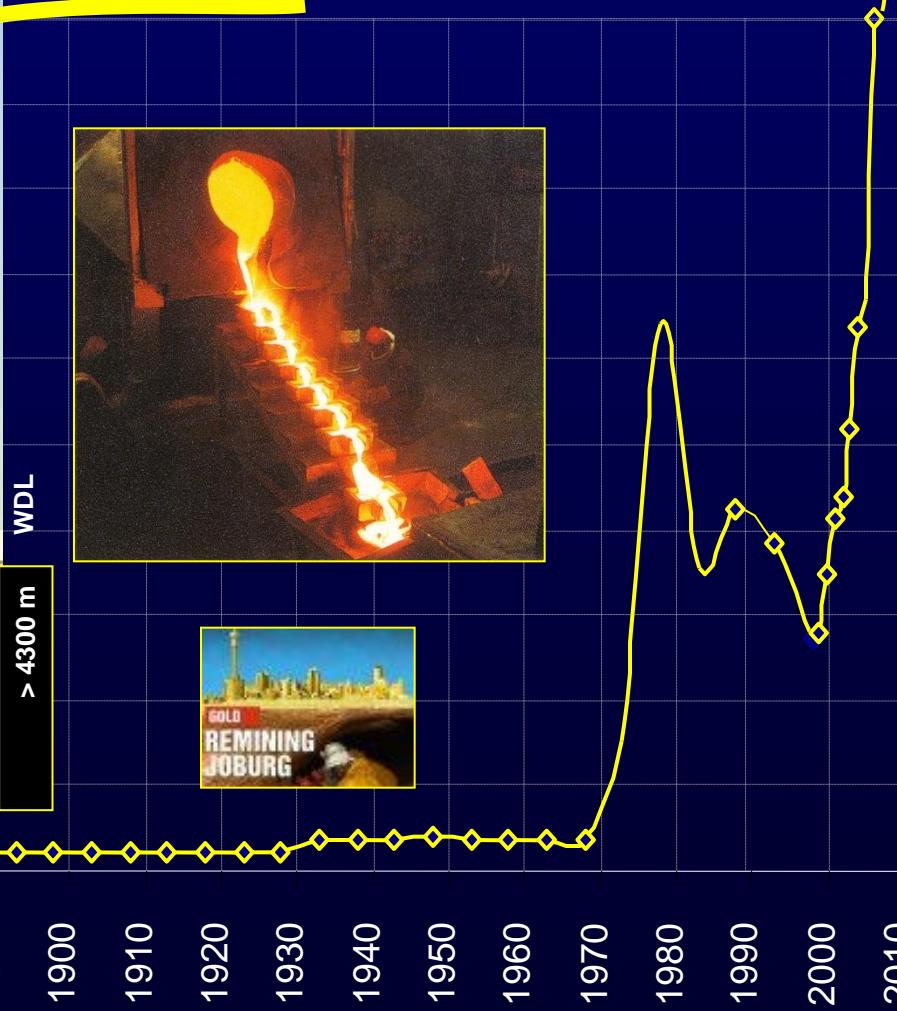
worldwide more steel is poured in 1 hour

...1700

## Au-prize [\$/oz]



,Sunset industry'?  
SA: 35.000t Au still available  
→ 15 kt accessible with current technology  
→ 20 kt ultra deep mining needed

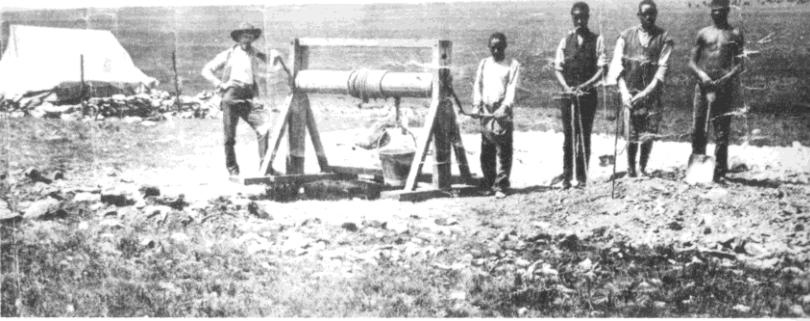


# 1. Background: Au-mining and dolomite



Case study 1:  
Dewatering (FWR)

GAUTENG



Early surface mining in Johannesburg, 1886

NORTH WEST PROVINE

KLERKSDORP

Case study 2:  
U pollution (WFS)

FREE STATE

FREE STATE



FAR WEST RAND

WEST RAND

CENTRAL RAND

Case study 3:  
Flooding/ AMD (CR)

EAST RAND

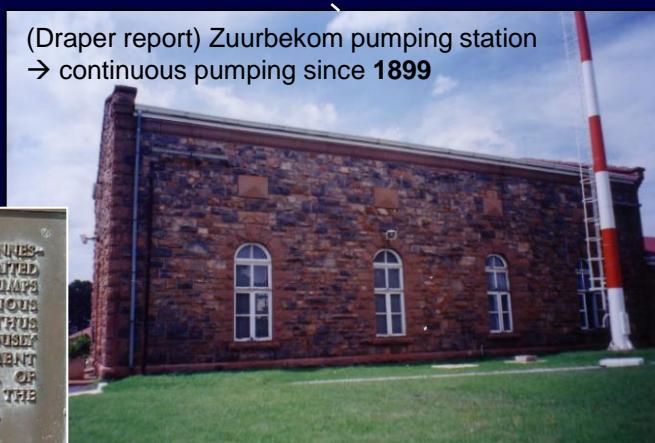
MPUMALANGA

EVANDER

100 km



**PUMPHOUSE**  
THE ZUURBEKOM PUMPHOUSE WAS ERECTED IN 1899 BY THE JOHANNESBURG WATERWORKS ESTATE AND EXPLORATION COMPANY LIMITED AND TAKEN OVER BY THE RAND WATER BOARD IN 1902. PUMPS HOUSED IN THIS BUILDING DELIVERED THE FIRST CONTINUOUS WATER SUPPLY TO THE CENTRAL WITWATERSTAND AND THUS ENDED THE CHRONIC WATER SHORTAGES THAT HAD PREVIOUSLY THREATENED PUBLIC HEALTH AND IMPEDED DEVELOPMENT OF THE TOWNS AND GOLD-MINES IN THE AREA. WATER OF CONSISTENTLY GOOD QUALITY HAS BEEN SUPPLIED FROM THE ZUURBEKOM WELLS WITHOUT INTERRUPTION SINCE 1899.  
National Monuments Council



Case study 1:

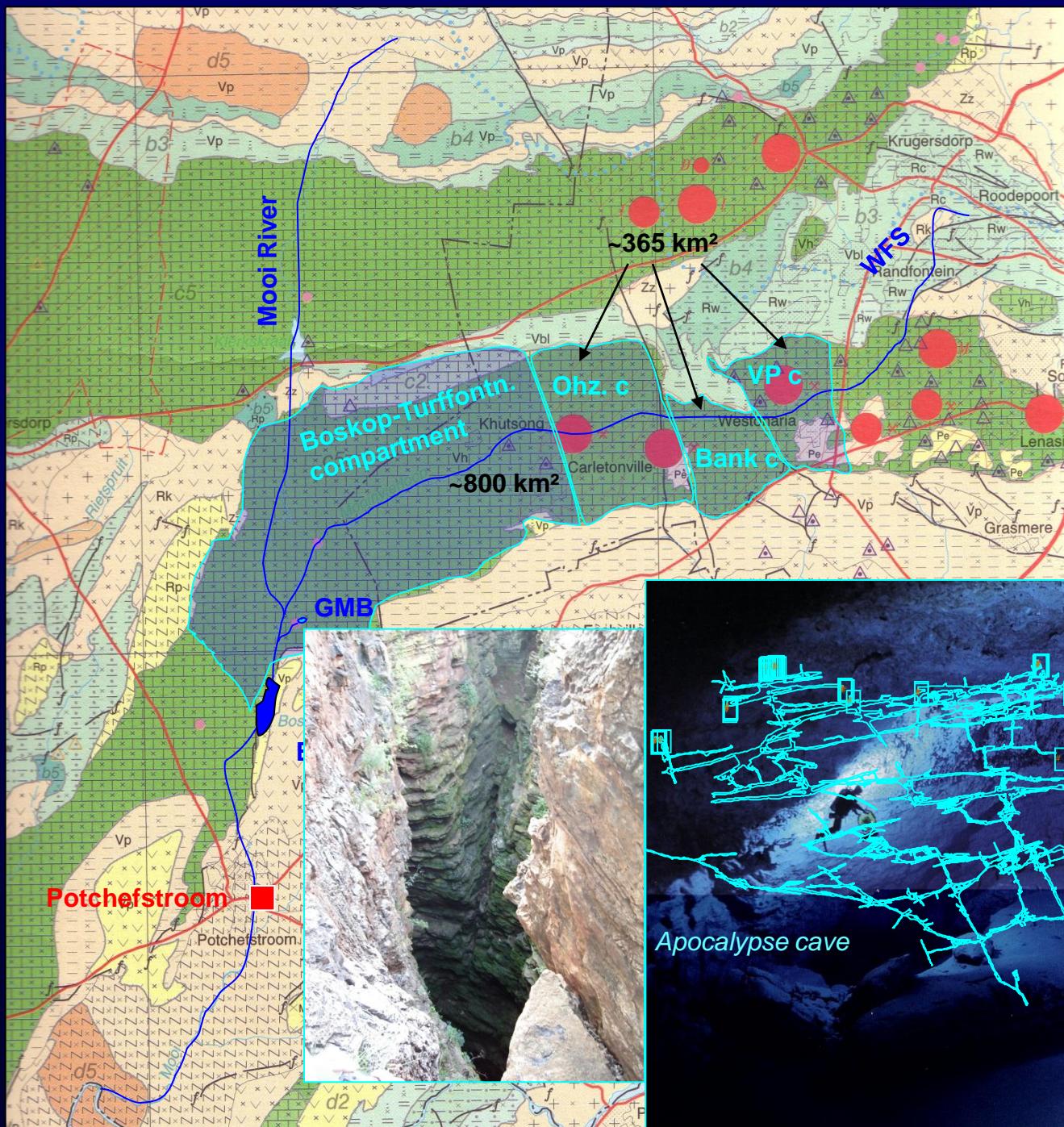
# Dewatering of karst aquifers

(Far West Rand)

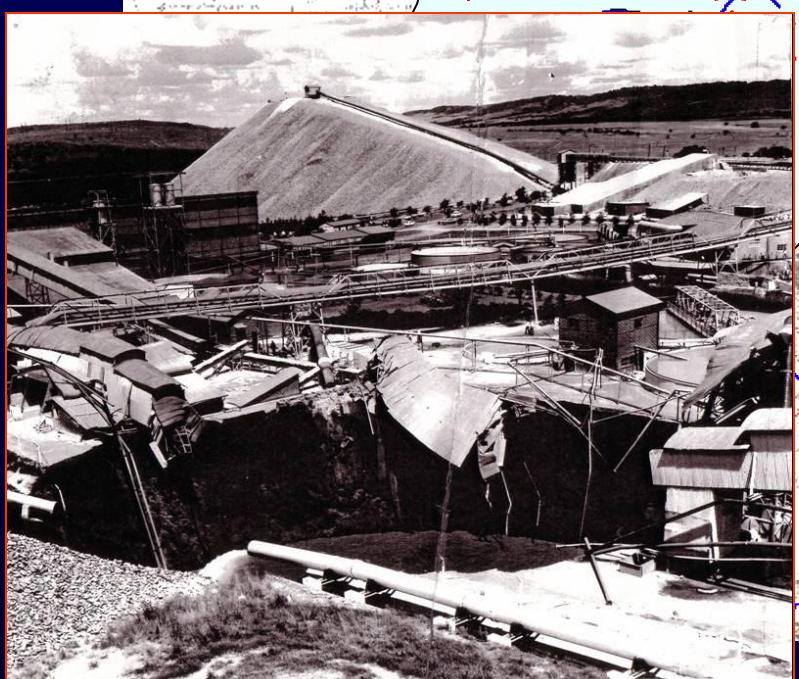
# Case study 1: Dewatering

Dolomitic  
compartments  
→ highly karstified

- 5 x longest caves in SA
- 2 x strongest springs
- storage capacity dewatered compartments > Vaal Dam



# Case study 1: Dewatering of karst aquifers - consequences



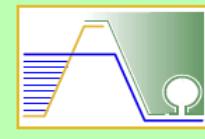
# Case study 1: Dewatering - altering recharge rates



# Case study 1: Dewatering – tailings injection into karst aquifers



**metago** Environmental Engineers (Pty) Ltd



Prepared For

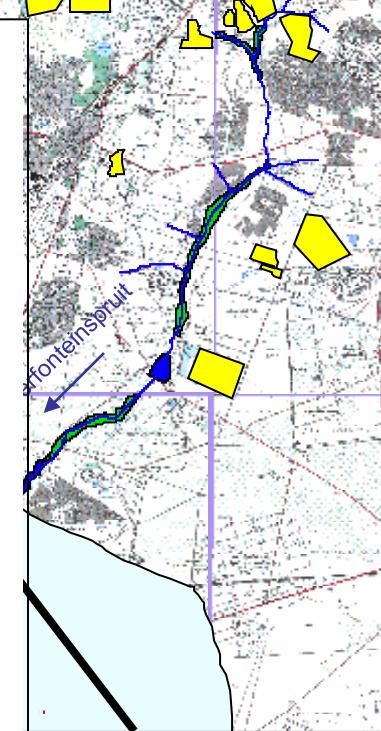
**Water Research Commission**

**THE ASSESSMENT OF THE IMPACTS ON GROUNDWATER QUALITY ASSOCIATED WITH THE BACKFILLING OF DOLOMATIC CAVITIES WITH GOLD MINE TAILINGS**

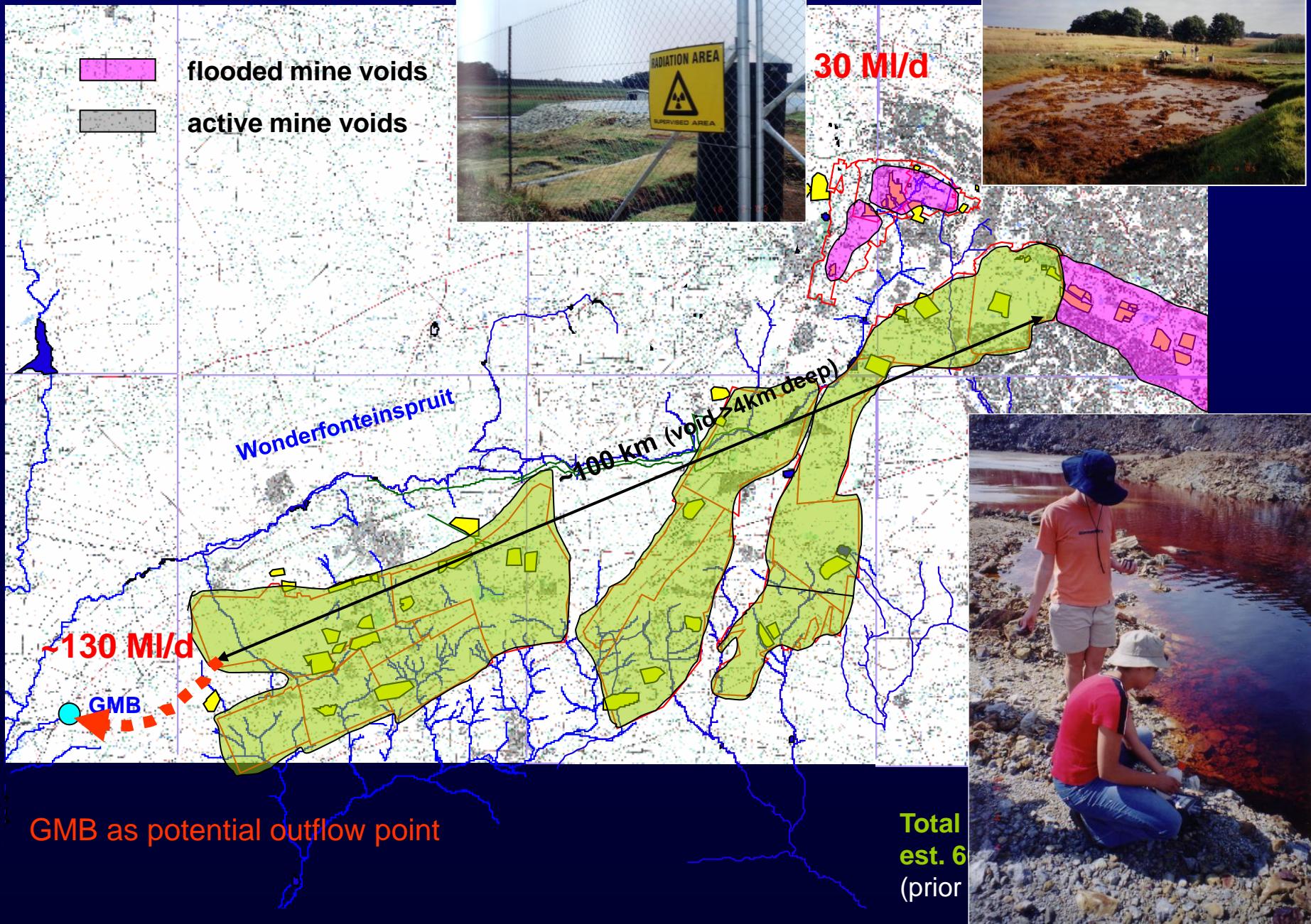
PROJECT NUMBER 115-002

REPORT NO.3 Final

January 2003



# Case study 1: Rewatering – decant of AMD



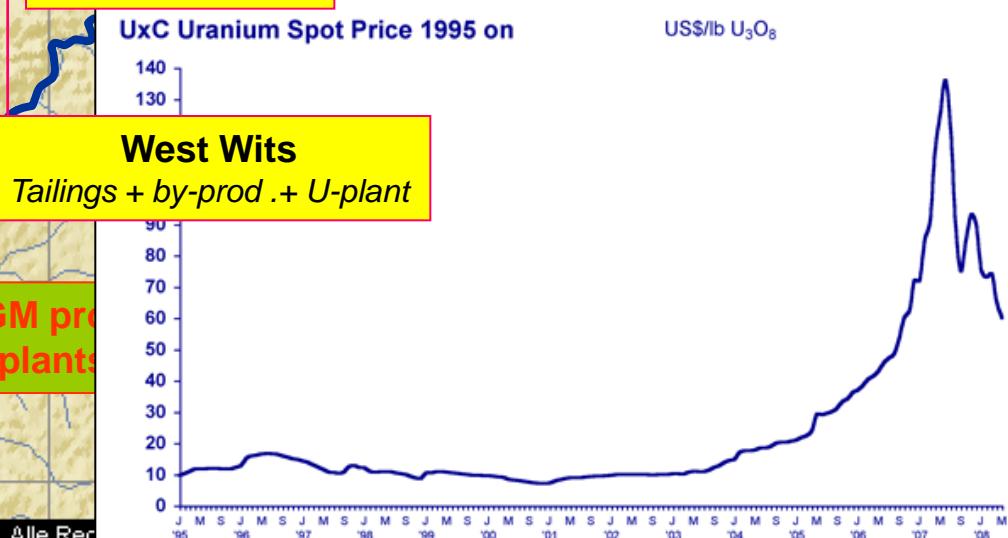
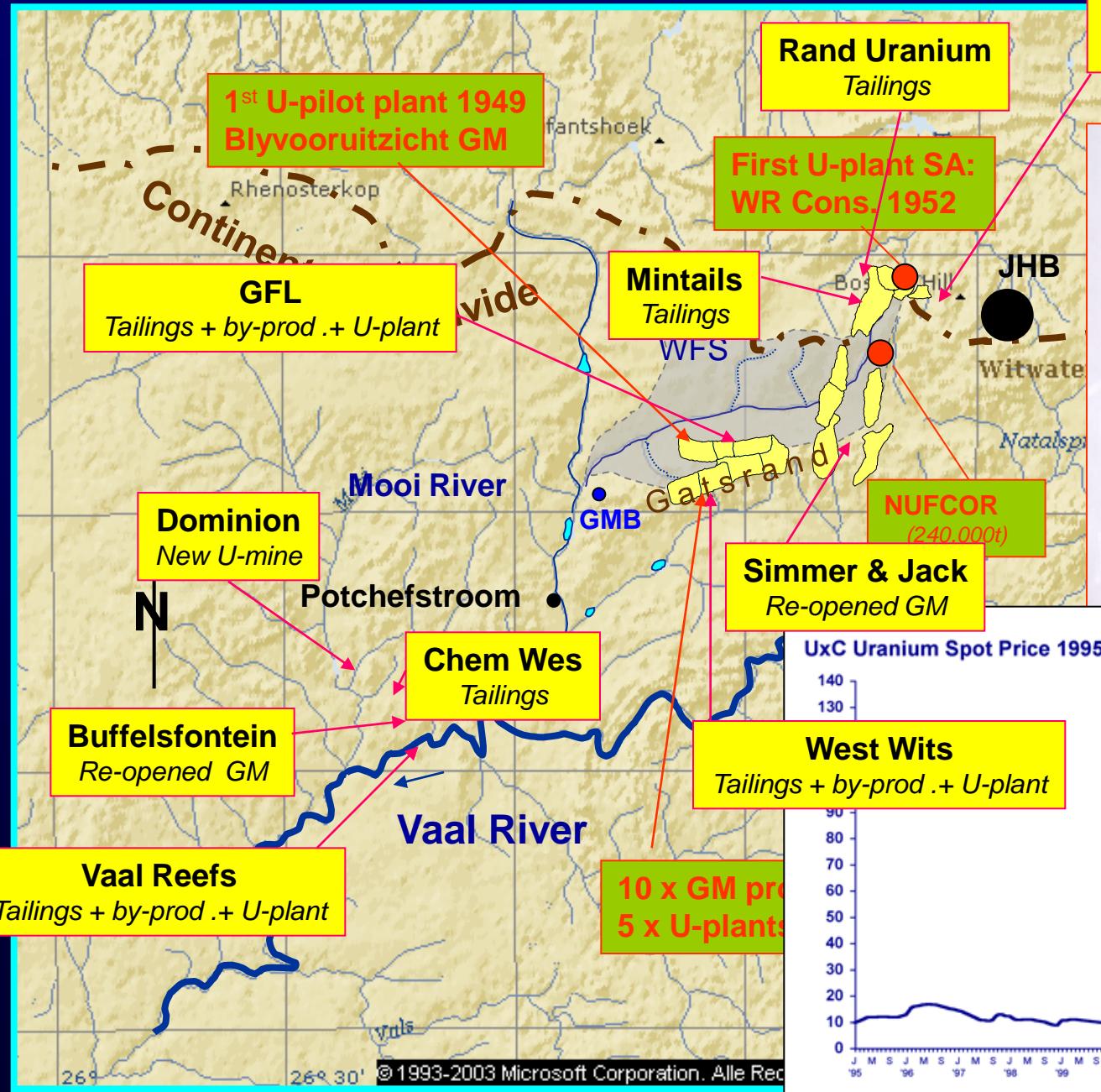
Case study 2:

# Uranium contamination

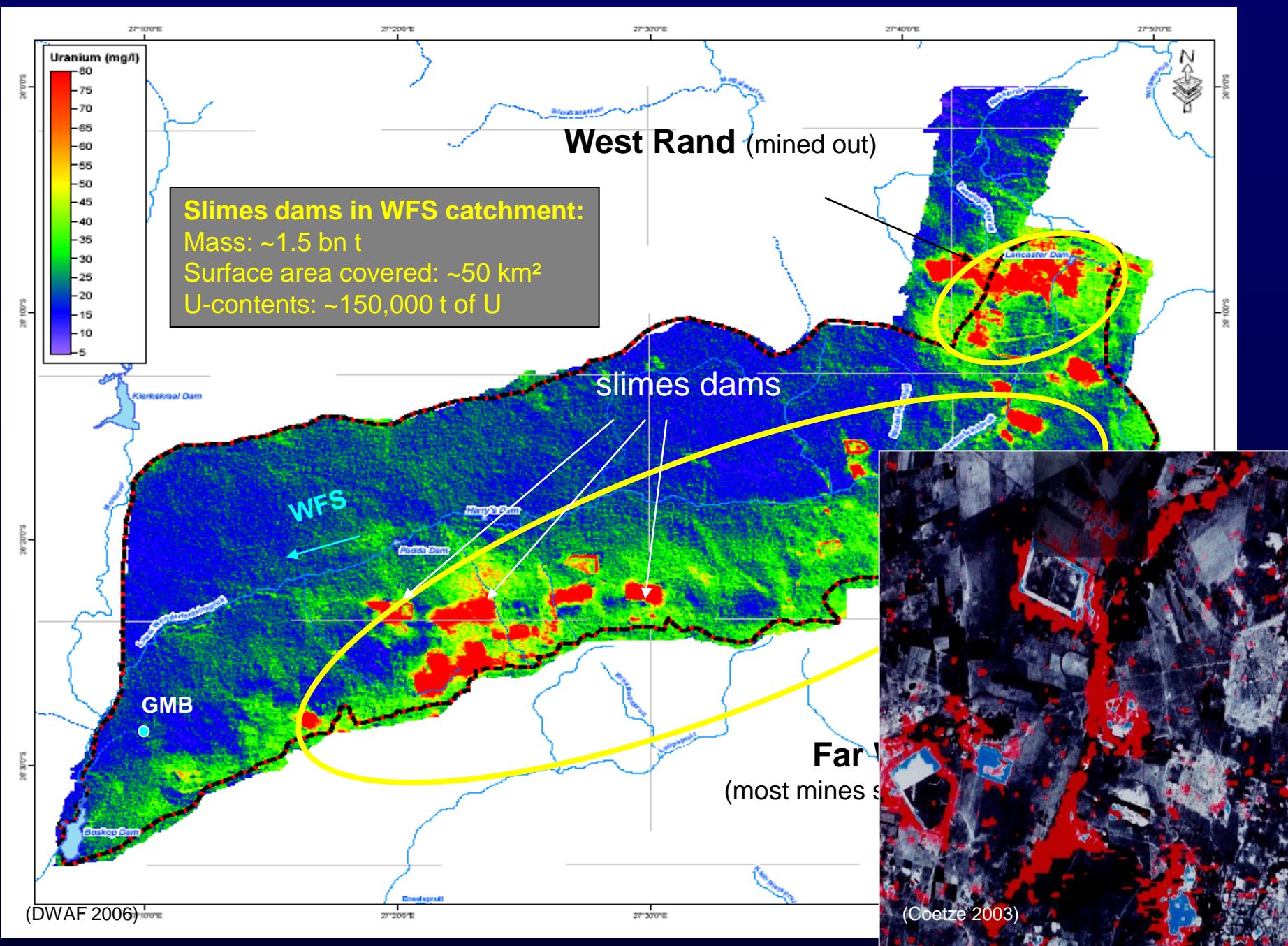
- Wonderfonteinspruit



## (2) Case study 2: U pollution - history



## (2) Case study 2: U pollution- sources



## (2) Case study 2: U pollution – media reports

1967

**Toxic water poses health nightmare**

GREENBELTS, dams, wetlands and a canal in that hundreds of people use as washing, have been identified as radioactive or toxic — within 100km of South Africa's biggest city.

Fifteen sites close to Johannesburg have been named in a 210-page report as being toxic. Some register radiation levels 200 times the legal limit. Long-term exposure to toxic chemicals and radioactivity has serious health side effects and may cause cancer.

However, the pollution could be far worse, the pollution could suggests, according to the report the authors, Professor Frank Wiede. He said the document should be used as a basis for further studies.

The report, dated April 30 and calls for "immediate action" in affected areas, compiled by international experts for the Department of Environment Affairs and Forestry National Nuclear Reg

One of the authors for an operation estimated to house up

inated water at t

Health exper

tests in affected

are all part ,  
system, and  
spruit and  
of Johan  
that was  
capital c

Altho  
proper  
publi  
over  
oth

Boskpoort, Vrydag 2 Februarie 2007

Mense en omgewing stik onder goud

Oct. 2010

## INSIGHT

# Hysteria, hearsay or hard facts?

Why is the evidence regarding the safety of the water in Potch so hard for the authorities to swallow?



POOR WILDE? The increasingly definitive Boskpoort could hardly dismiss studies which heavily criticise its water source. But experts say the public should take the pollution seriously.

PETER VAN LIESHOUT

**INCREASINGLY** draconian laws on water scarcity are sure cause for concern

water scarce areas as well as present regulation to combat localised flooding.

Water scarcity is a problem that is not unique to South Africa. Many countries around the world face similar challenges. The question is whether South Africa is addressing the issue effectively.

Water scarcity is a complex issue that requires a multi-pronged approach. It is not enough to rely on regulations alone. We must also invest in infrastructure, such as dams and irrigation systems, to ensure that we can meet our water needs.

South Africa is taking steps to address water scarcity, but more needs to be done. The government must continue to invest in infrastructure and regulations to ensure that we can meet our water needs.

more than 1000 cases resulting in institutionalised child abuse. This has led to increased attention to the issue of child abuse and neglect.

"Once the authorities take responsibility for the welfare of children, they will be held accountable for their actions and inactions," says Dr. David Smith, a member of the Child Abuse Prevention and Response Committee.

"We must stand up and demand that the authorities take responsibility for the welfare of children. This is a critical issue that requires urgent attention and action."

Smith adds that the committee is calling on the government to increase its efforts to prevent child abuse and neglect.

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Jou weer-sI, Jou koerant  
Beeld  
Dinsdag 31 Julie 2007 R3,95

nyne bedreig... bes  
Beeld, Vrydag 23 Oktober 2009

op dalk  
an uit  
krane  
n die brein aan

fonteinspruit gestyg.  
Die Boskpoortdam kry sy water uit dié waterdraai.

Winde het bygevoeg uraan, 'n radioaktiewe swaarmetaal, hou baie ernste gesondheidrisiko's vir die mense van informele nedersettings by Carletonville, Khotusong en Fochville in omdat hulle steeds water uit kanaal direk uit die rivier drink.

Van die uraan wat die algelope in die Wonderfontein uit beland het, het sedertdien oplos weens suur mynwa-

et. Dit is volgens Wilde tereg dat die uraanvlakke tonderfonteinspruit ver-

ap (waar besondere ntrasies uraan in die rkom) en waar "pale" in bloedanker ly.

studies in gebiede condom ou uitge- nyne in die voor- litsland en die 'blik woon, het verkte uraan tas aan nie, maar van.

armers mainatin they are be- y and that thousands of people are exposed to it every day. According to the World Health Organization, exposure to radon is a major risk factor for lung cancer.

According to a recent study, about one in ten homes in South Africa contains radon levels that exceed safe limits. Radon is a radioactive gas that is naturally occurring in soil and rock. It is released into the air through the process of decay and can enter homes through cracks in floors and walls.

Radon is a known carcinogen and can cause lung cancer if inhaled over long periods of time.

4 November 2005

## (2) Case study 2: U pollution - studies

### Selected studies (16 out of 35)

#### 1967 – CoM/ DWAF – Onderstepoort study on health

1991 – Deelkraal GM – U-levels in urine of miners

1991 – Pulles (COMRO) – Health hazard of radionuclides

1992 – Slabbert (Dfnt. GM) – Radioactivity concentrations

1996 – IWQS (DWAF) – Screening on water radioactivity

#### 1997 – IWQS (DWAF) - Radioactivity Monitoring in Water

1998 ... ongoing: DWA - Mooi Rivier radioactivity survey

2000 – Wade et al. (CSIR for WRC) – Radioactivity in sediments

2000 - Nel (Potchefstroom municipality) – U-monitoring

2002 – CGS (for DWAF) – Radioactivity in sediments of rivers

#### 2003 – Metago (for WRC) – U-pollution by filling sinkholes

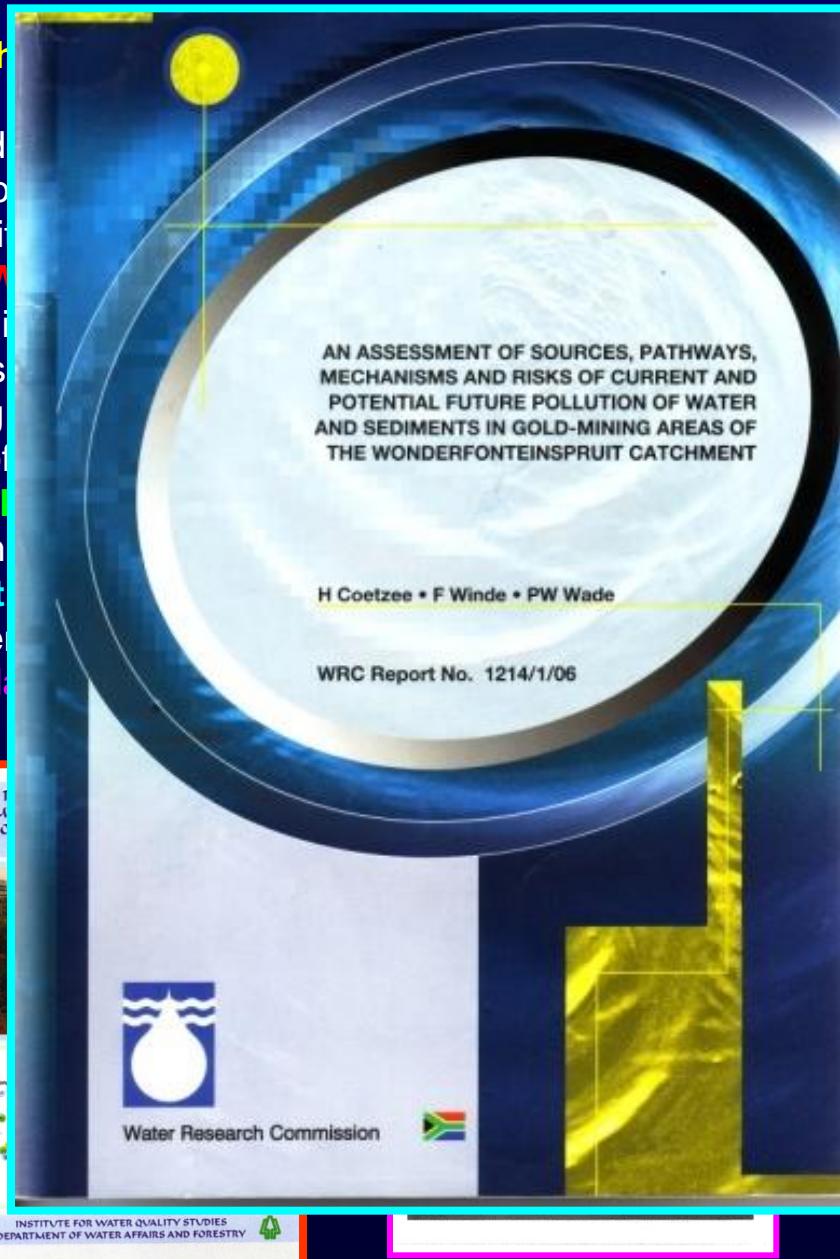
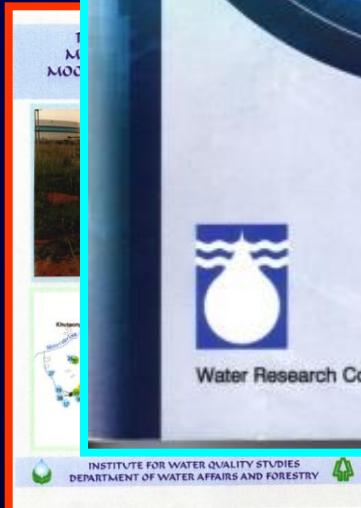
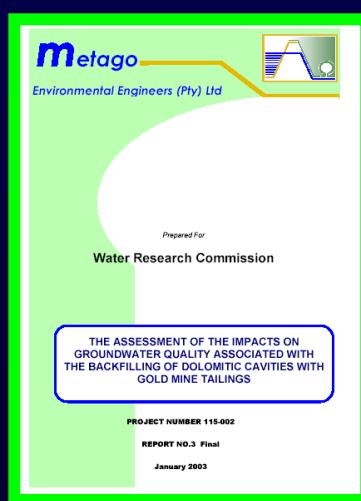
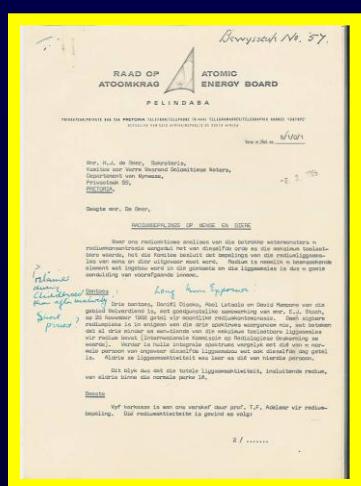
2004 - Blyvooruitzicht Gold Mine U-monitoring program

#### 2004 – Coetzee, Winde, Wade (WRC 1214) - U-pollution

2005 – DWAF – U-contamination of mine canal sediments

#### 2007 – NNR (Brenk report) - radioactive dose calculation

2007 – Sediment analysis by GFL Ltd. (WAG)



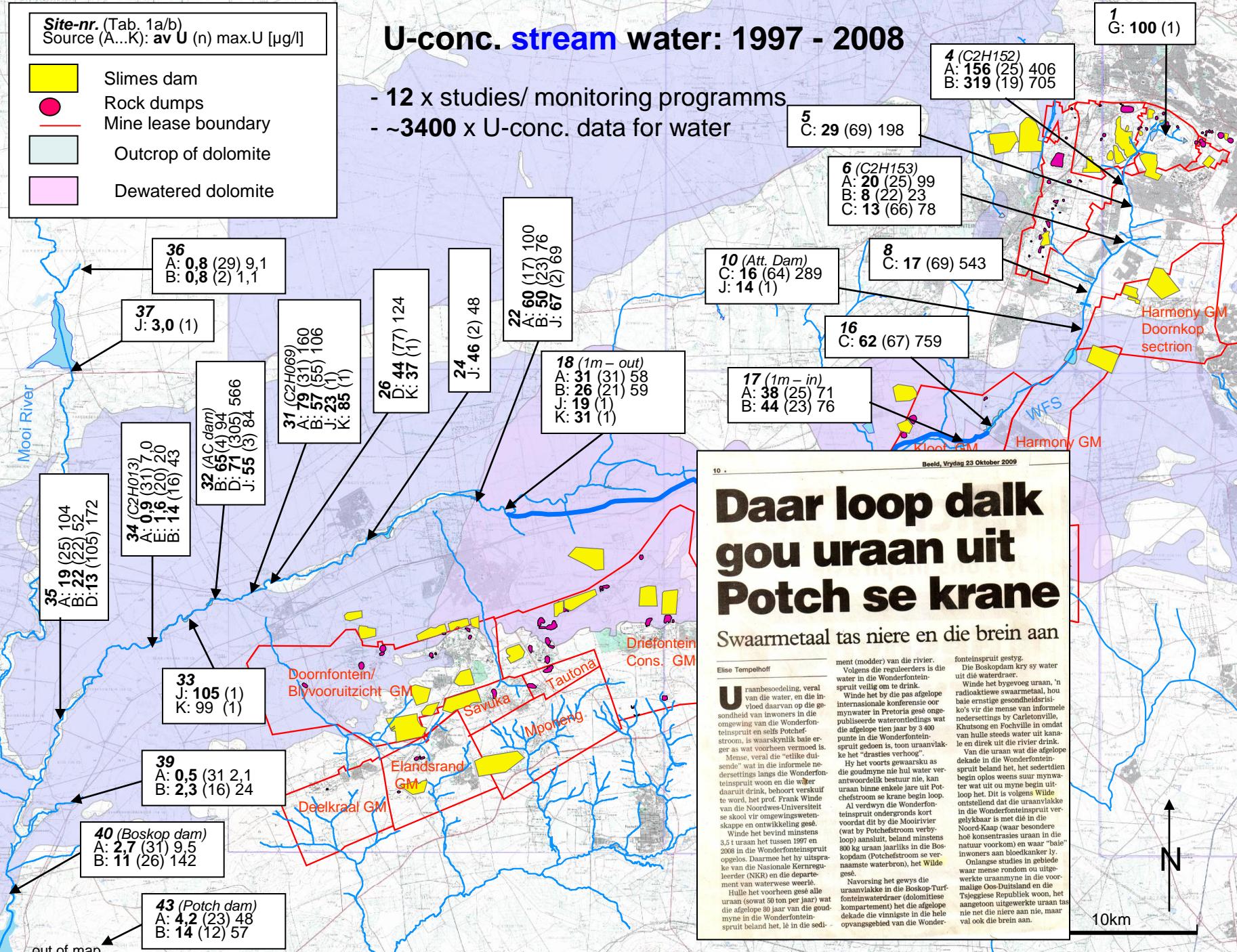
2008-2011: 10 x more studies added

Site-nr. (Tab. 1a/b)  
Source (A...K): av U (n) max.U [ $\mu\text{g/l}$ ]

- █ Slimes dam
- Rock dumps
- Mine lease boundary
- Outcrop of dolomite
- Dewatered dolomite

## U-conc. stream water: 1997 - 2008

- 12 x studies/ monitoring programmes
- ~3400 x U-conc. data for water

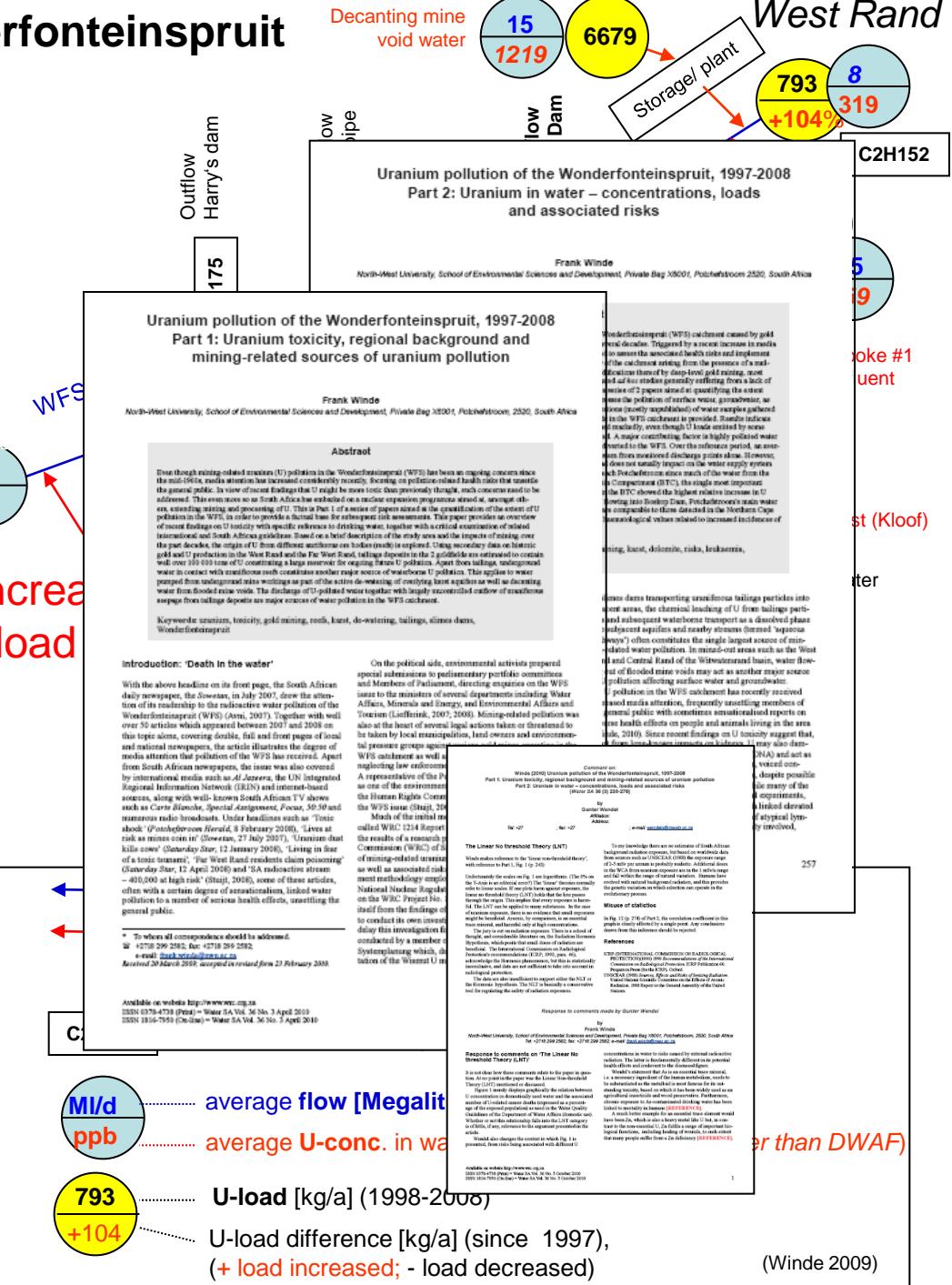
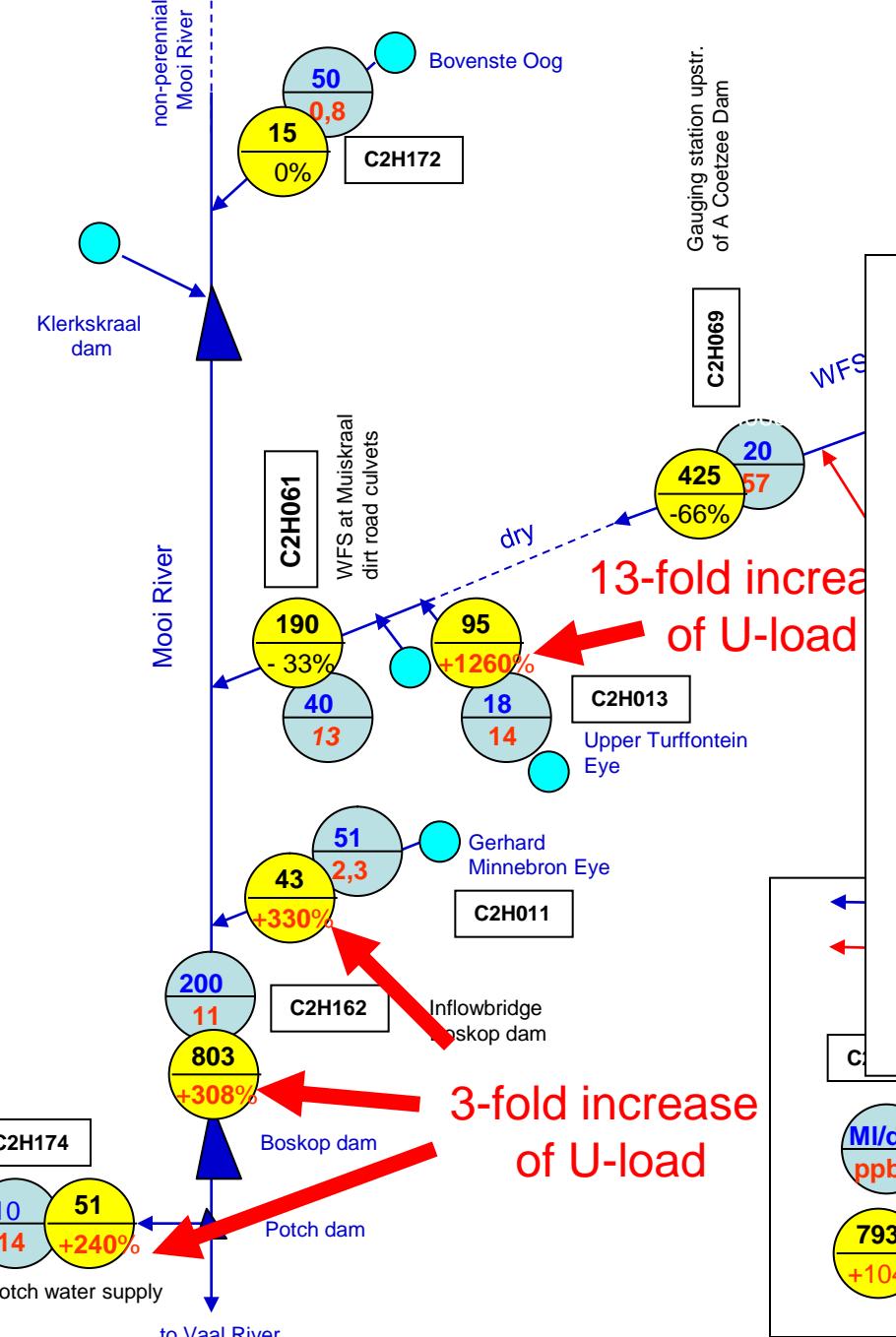


1  
G: 100 (1)

10km

N

## (2) Case study 2: U pollution - Wonderfonteinspruit

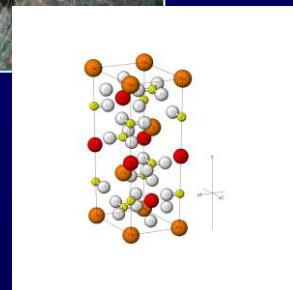
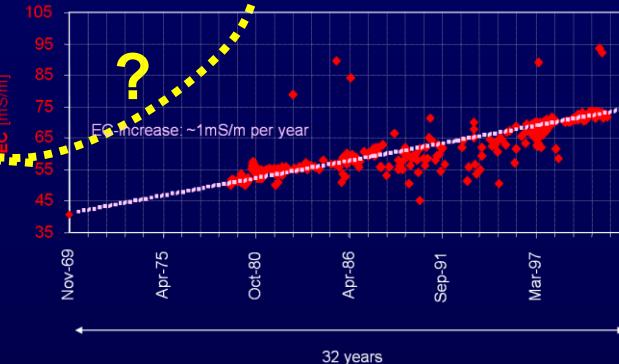
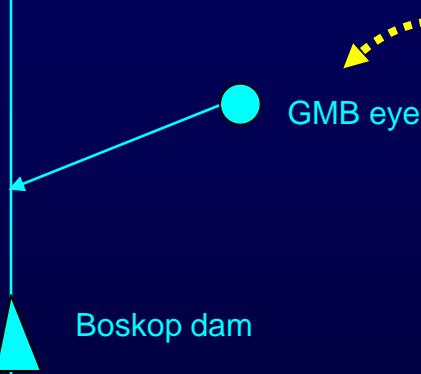
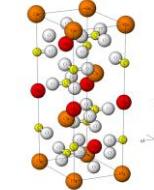


## Case study 2: U-pollution



Wonderfonteinspruit

~3.5 t/a



Natural dissolution of dolomite results in abundance of:  
 $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{HCO}_3^-$

each ion found to reduce U-removal efficiency of standard potabilization processes to 60%

(Baeza, 2008)

i.e. In dolomitic water U is more likely to slip through treatment plants

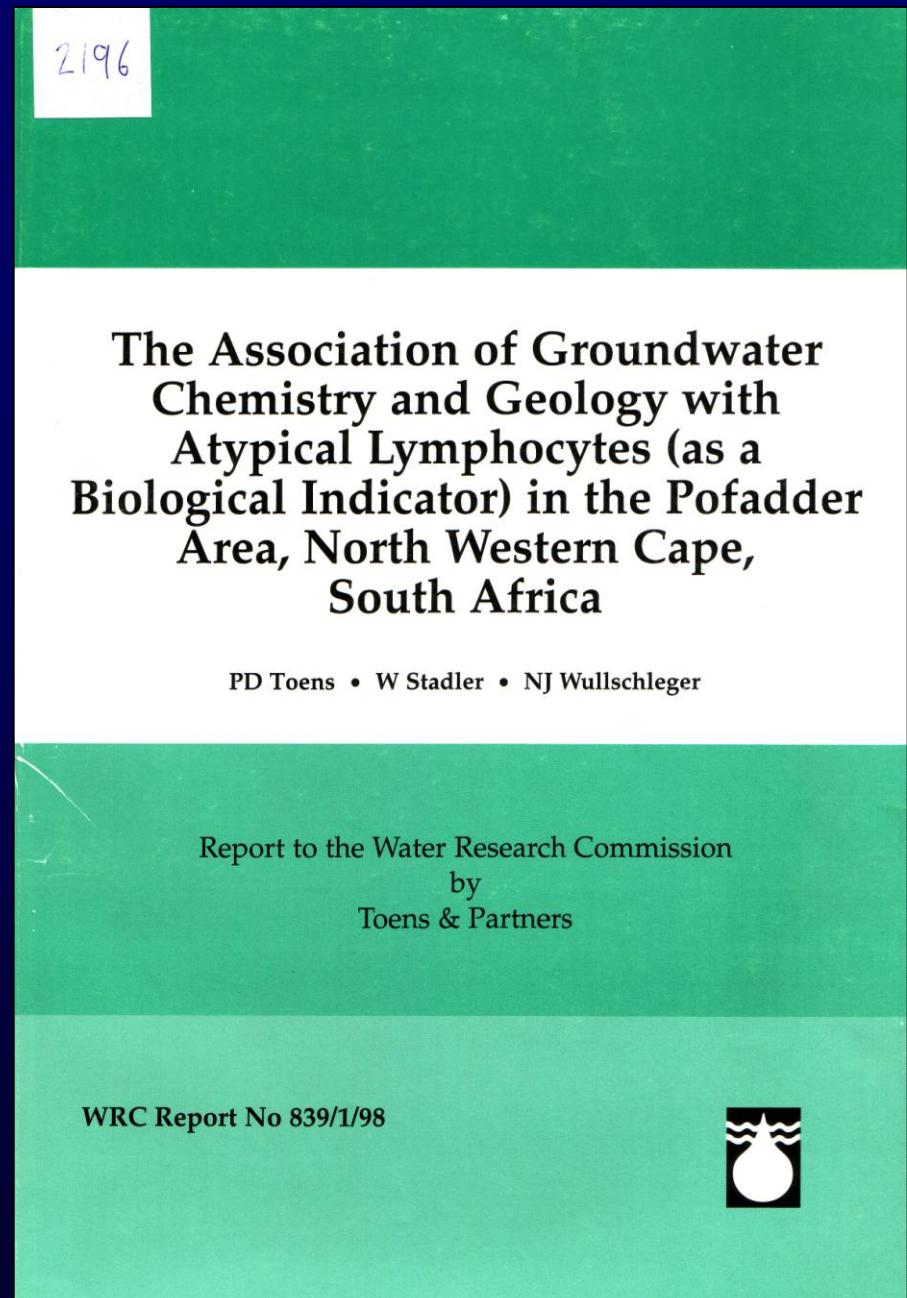
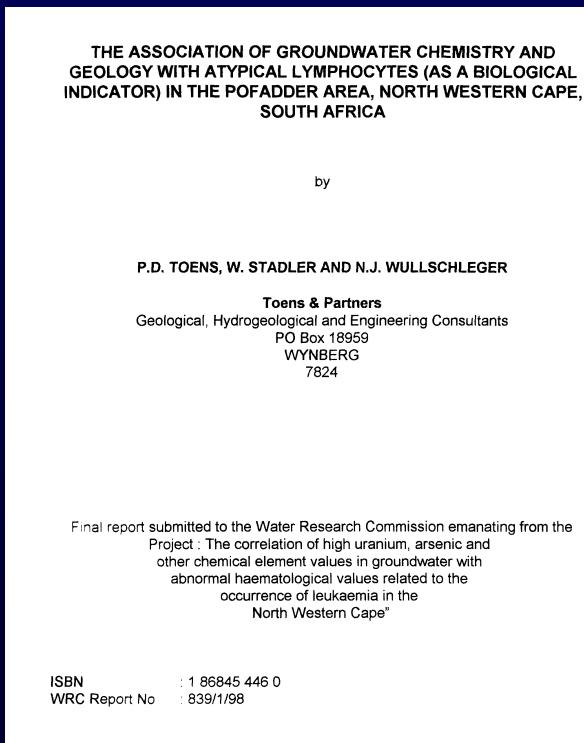


2003: Kettle scale  
21 vs 1 ppm

Potch water works  
standard potabilization:  
*chlorination, flocculation, filtration*

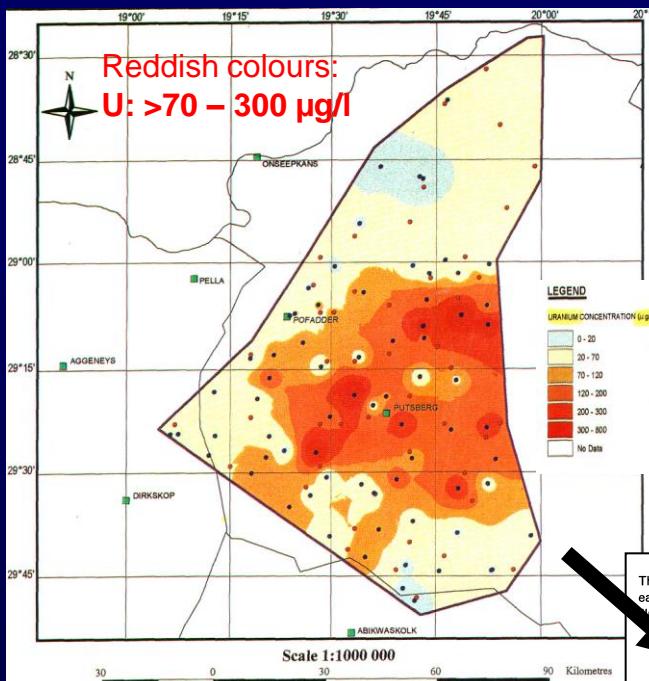
## Case study 2: U pollution – health effects

- 1995: Dr de Villiers (Stellenbosch Univ.) high number of leukaemia patients from area around Pofadder (N-Cape)
- blood samples of **418 people** from **120 localities** (>16 a of age, 1993)
- water quality: **126 boreholes**, AEC data (early 1980s)

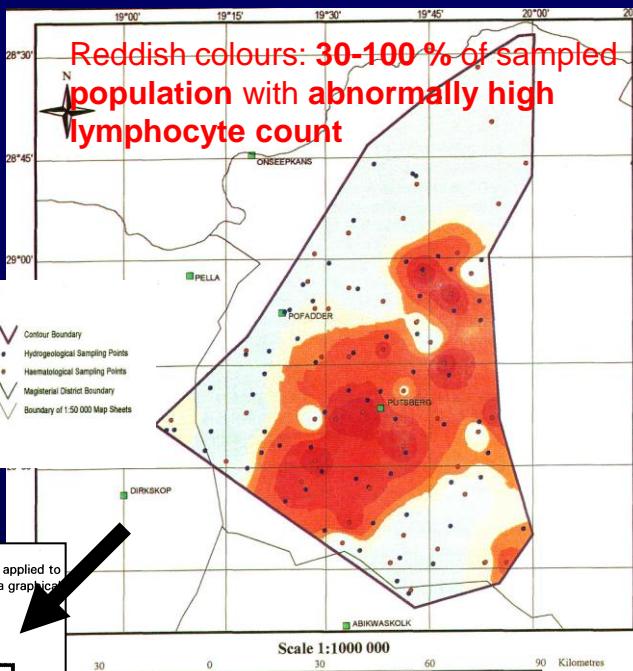


## (2) Case study 2: Uranium pollution – health effects

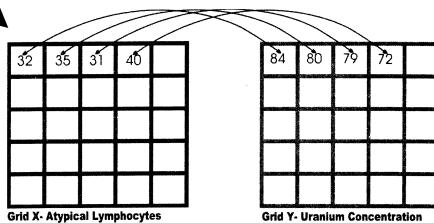
### U-levels in 126 boreholes



Lymphocyte count  
(418 residents from 120 localities)



The correlation coefficient was derived from the standard formula, which was applied to each of the roughly 500 000 cells in the grid being analysed. The following is a graphic illustration of the procedure employed:



Each grid cell of the first grid is compared to the geographically identical cell of the second grid. The statistical relationship is quantified by using the following formula:

**500 000 grid cells correllated**

$$\rho_{xy} \text{ (correlation coefficient)} = \frac{\text{Cov}(X,Y)}{\sigma_x \sigma_y}$$

where  $\text{Cov}(X,Y) = \frac{1}{n} \sum_{i=1}^n (x_i - \mu_x)(y_i - \mu_y)$

$\sigma_x$  = STANDARD DEVIATION OF X

$\mu_x$  = ARITHMETIC MEAN OF X

WFS: >300 (upper) ... 80 µg/l (lower)  
Mine water: 200 ... >3000 µg/l

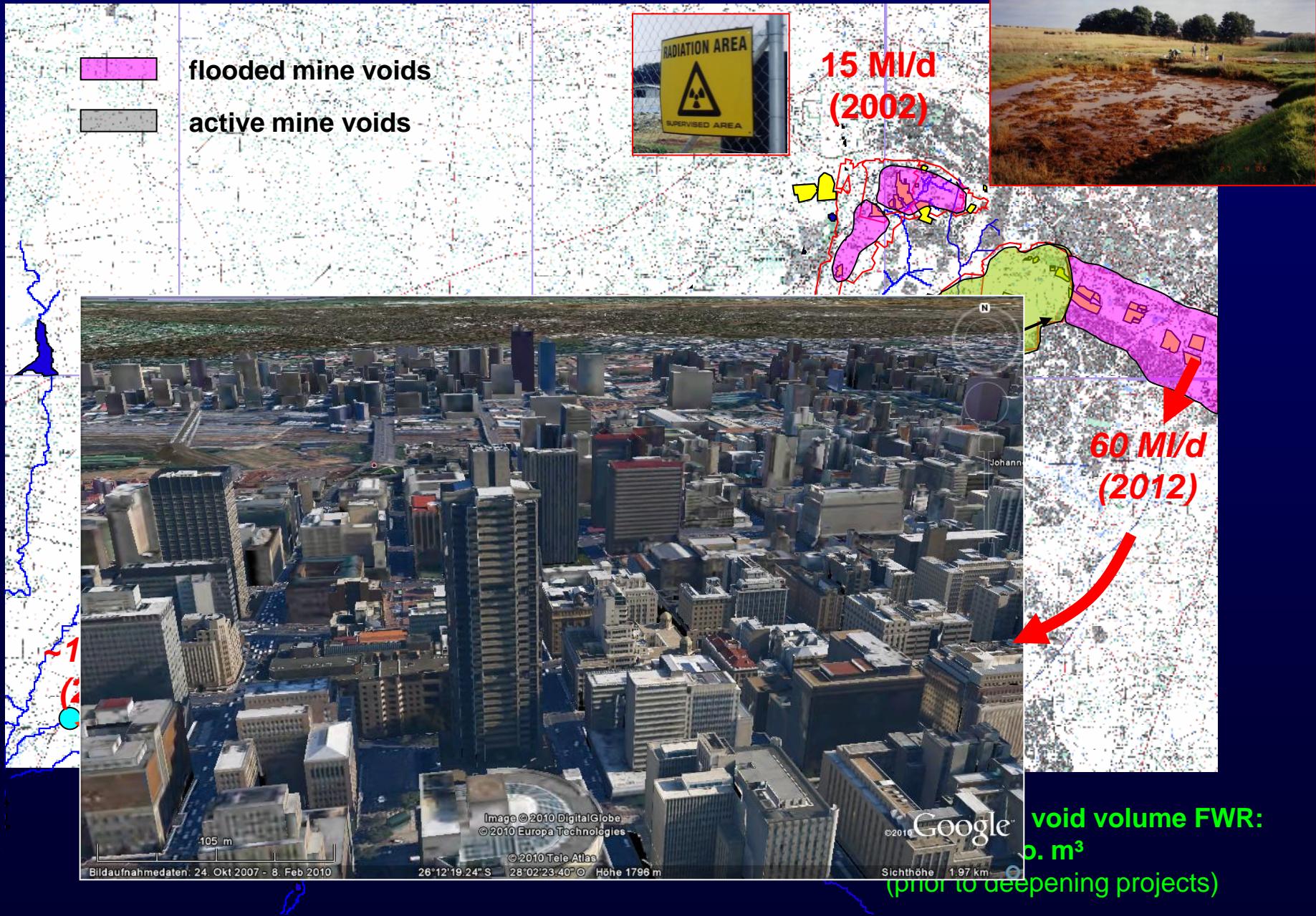


→ 3 x follow-up studies confirmed high U-levels and domestic use of water

## Case study 3

# Flooding of mine voids **(AMD)**

## (2) Case study 3: Flooding of mine voids



## (2) Case study 3: Flooding of mine voids



### Toxic mine water 'causes more quakes'

WYNDHAM HARTLEY  
Parliamentary Editor

CAPE TOWN — Monthly seismic events in Johannesburg and the West Rand and East Rand have almost doubled since acid mine drainage began to fill derelict mines in 2008, Parliament's water and environment affairs committee was told yesterday.

The government is racing against time to get pumping stations and treatment plants in place before March next year when the toxic water is predicted

to reach the environmentally critical level of 150m below the surface. The committee is holding public hearings to assess progress towards a solution.

Henk Coetze, one of the government's team of experts that investigated acid mine drainage, said increased seismicity was one of the risks associated with the flooding of mines. The water lubricated faults in the earth's crust and allowed them to move.

Mr Coetze said since pumping stopped at the ERPM mine in December 2008, the monthly

average of seismic events had risen from 5.9 to 11.7. Some were strong enough to cause concern.

He also confirmed fears about the pollution of underground water resources, possible land instability and the threat to the foundations of buildings.

Once the 150m level was breached, the acid water would enter shallow aquifers and contaminate groundwater, Mr Coetze said. It would dissolve dolomite and cause underground erosion, increasing the possibility of sinkholes. On the western basin

of the Witwatersrand, about 30 megalitres of acid water was decanting every day, threatening the Cradle of Humankind.

Committee chairman Johnny de Lange demanded the names of mining houses responsible for acid drainage and was told that in the west it was Rand Uranium, Durban Roodepoort Deep and Mintails. A water affairs official, Marius Keet, said the problems in the central basin were caused by the ERPM mine, and in the eastern basin by the Grootvlei mine. hartleyw@bdfm.co.za

INGS IS OORDREW

6 The Times Wednesday July 28 | 2010

# Mine water disaster looming

Seepage can cause cancer in humans

SIPHO MASONDO

RADICAL action is needed to avert the looming catastrophe caused by highly acidic, toxic water seeping from the Grootvlei mine, on Gauteng's East Rand.

So said Maggie Sotyu, chairman of the parliamentary committee on water and the environment, after yesterday's visit to the mine, near Springs.

Sotyu and the committee are on a tour of areas under threat from acid water draining from abandoned mines. The polluted water can cause cancer and serious damage to the environment.

"Radical intervention by all stakeholders is needed. Something is not right but we don't know what exactly it is, that's why we are here," said Sotyu.

"And I don't see us winning that battle without a straight fight."

Grootvlei has been discharging thousands of litres of polluted water into the Blesbok Spruit.

The mine is owned by former president Nelson Mandela's grandson, Zondwa Mandela, and by President Jacob Zuma's nephew, Khulubuse, through Aurora Empowerment Systems. The owners made headlines recently for failing to pay their workers.

Grootvlei's management told the committee that it was treating 40 million litres of acid water a day but had the capacity to treat 120 million litres a day.

Chemical engineer Brett du Toit told the committee that the acid water draining from the mine was about 770m underground but could start seeping to the surface within a few months if not attended to urgently.

He said that if the water level rose by a mere 30m the mine's only working pump, responsible for pumping out the polluted water, would be flooded.

If the pump were flooded it would not operate. All the mine's shafts would then be flooded and mining would become impossible.

Du Toit said the government stopped its R1.2-million subsidy in October and it cost Aurora "over R6-million to treat acid water draining from the mine every month".

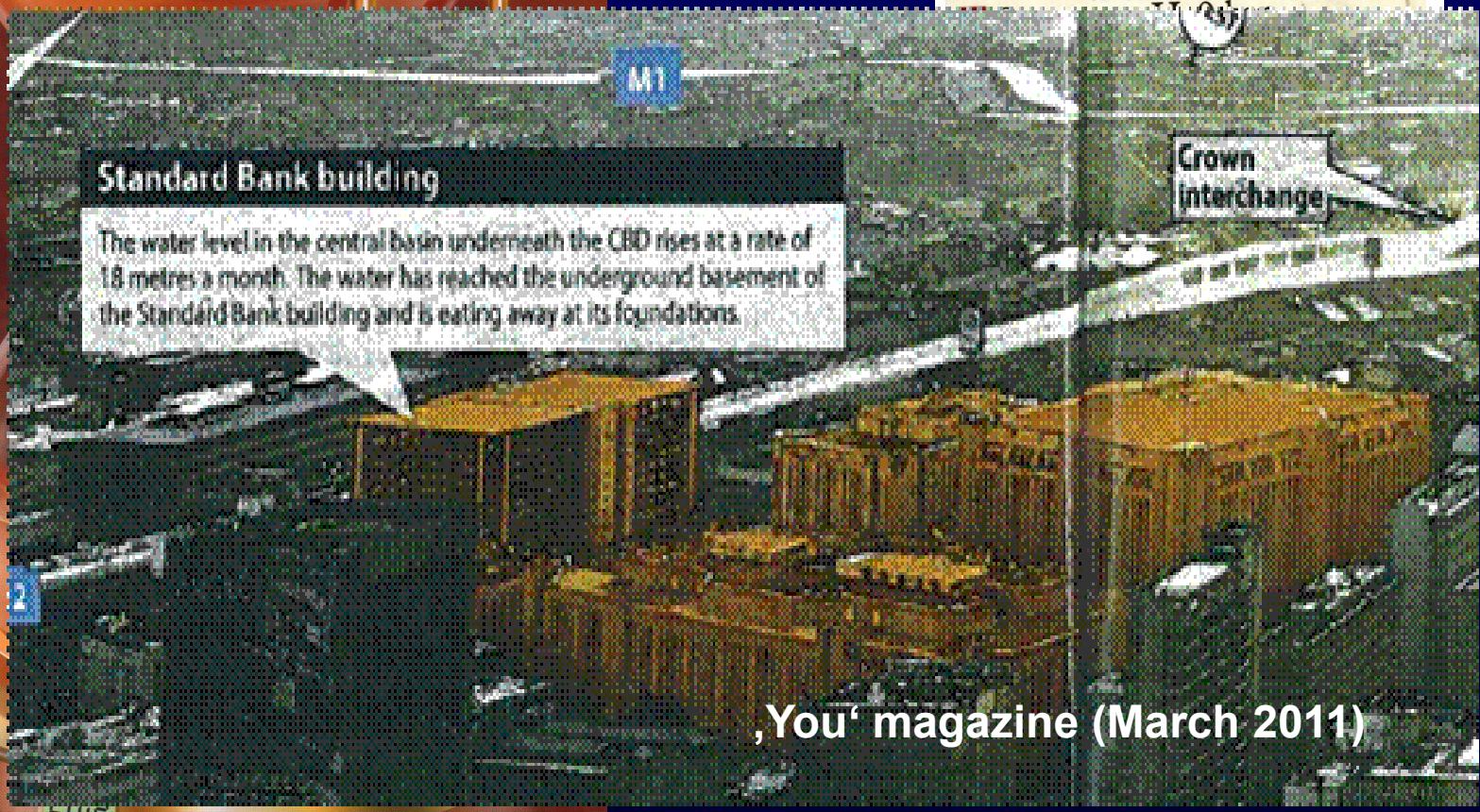
The mine had the potential to produce about 200t of gold over the next 70 years.

Mandela said the owners were serious about making the mine work.

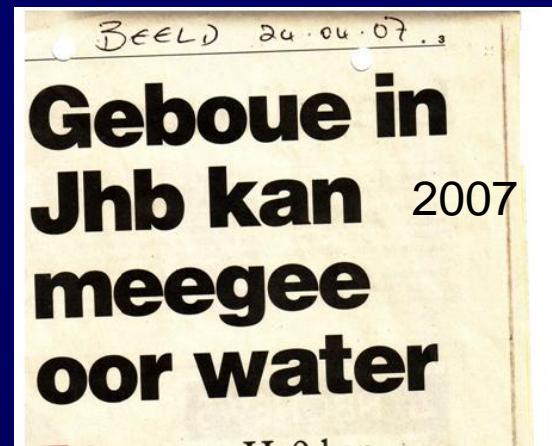
"We've made our mistakes in this operation ... [but] we come with the intention of making a success."

Business Day 22/01/2011

## (2) Case study 3: Flooding of mine voids

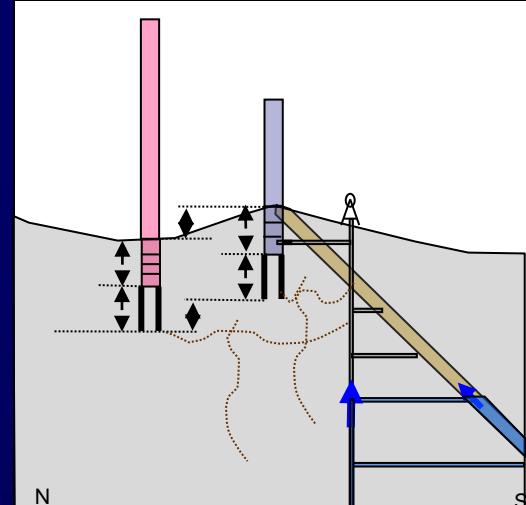


You' magazine (March 2011)



### (3) Case study 3: Mine void flooding

Findings: (1) No flooding risk for CBD



Safety margin to PBL: 106 m (Std. Bank) and 90 m (ABSA)



Shafts hydraulically connected at various deeper levels

## (2) Case study 3: Flooding of mine voids

(1) No flooding risk for CBD (single basin, many open shafts)

(2) No sinkhole risk for CBD (no dolomite)

(3) Ingress sources mainly from surface (50-60%), many manageable

(4) Lower than predicted decant volume (35 vs. 60 MI/d)

→ pumping = ingress = decant → overestimation

→ - service water + natural cut off of ingress sources

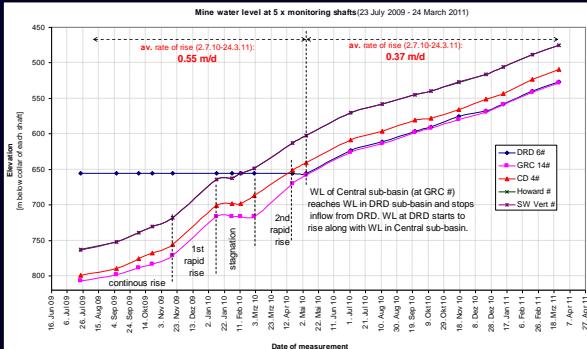
(5) Primary pollution sources mainly on surface not underground

→ plastic stope closure (>70% void volume reduction)

→ neutral water decant WB

(6) Lesser pollution impact on streams than predicted

(7) Slower rise than predicted, less depended on rainfall (37 vs. 57 cm/d)



Enough time to consider alternative to very expensive pump- and treat option currently proposed → sustainable low-cost, low-energy solution possible



# (3) The future?



# Karst aquifers in the Far West Rand

### (3) The future: Post-mining opportunities (FWR)

#### Underground pump-storage schemes

ESKOM principle of **pumping scheme** at Sterkfontein dam: day-night tariff differences

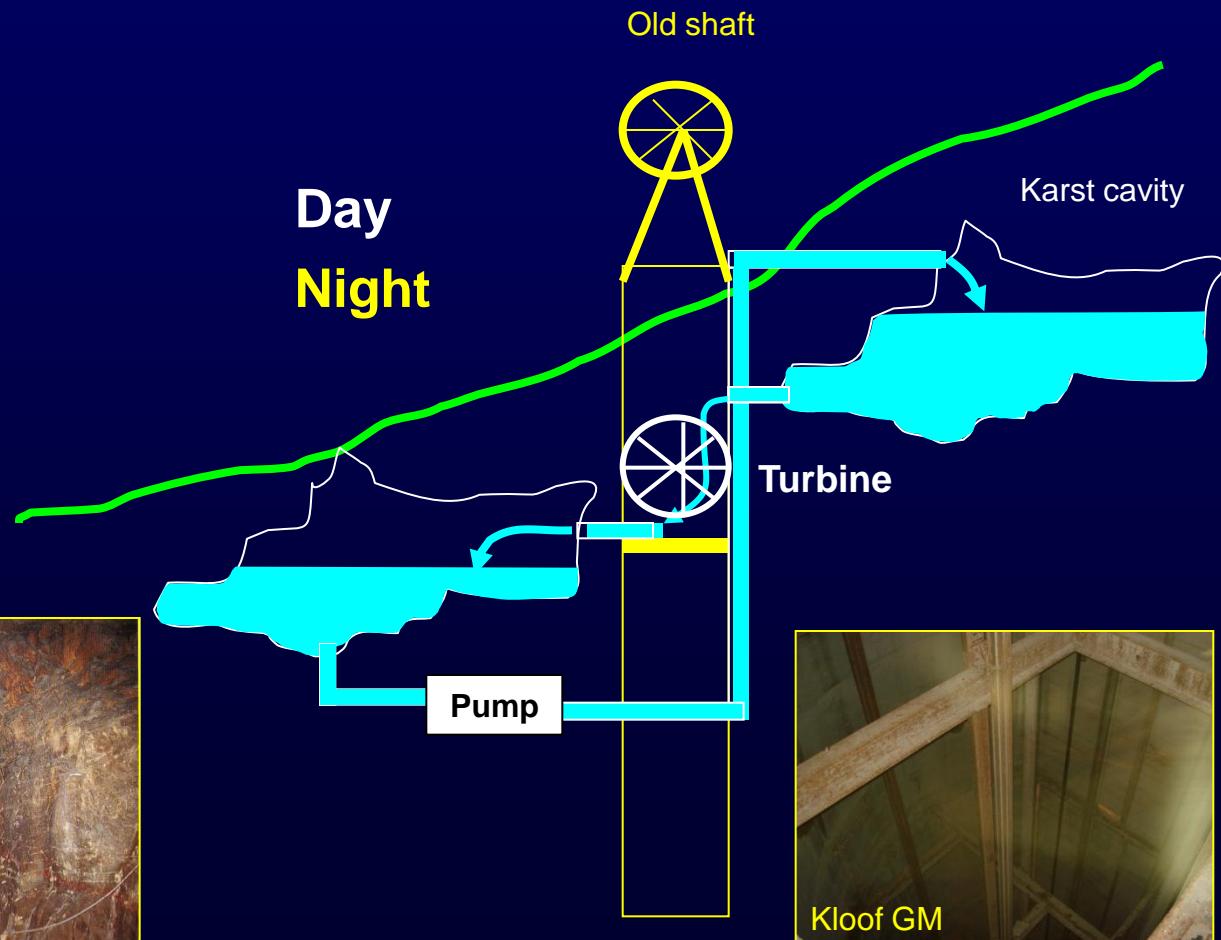
→ **Use existing underground infrastructure** such as shafts, reservoirs, pumping chamber, pipelines, turbines, etc.

→ no electricity losses through long-distance transport

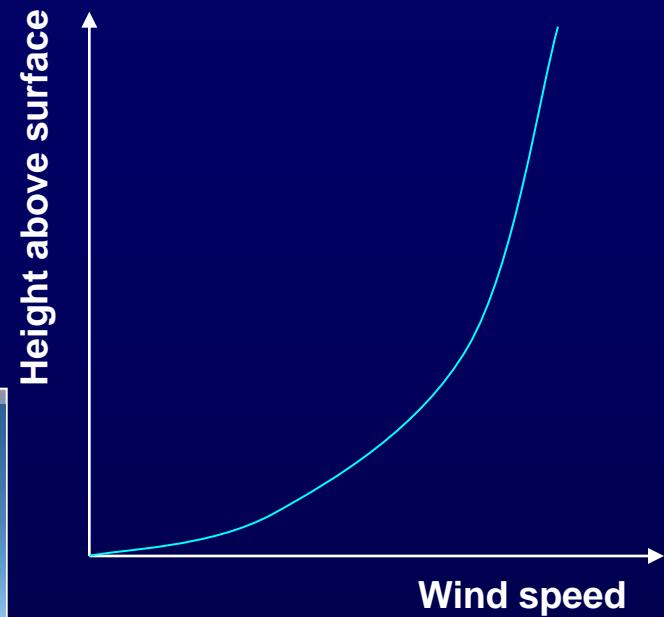
→ cost neutral pumping of water for irrigation/ utility



Construction of underground hydropower pumping scheme in karst area on the island of Java (Indonesia)



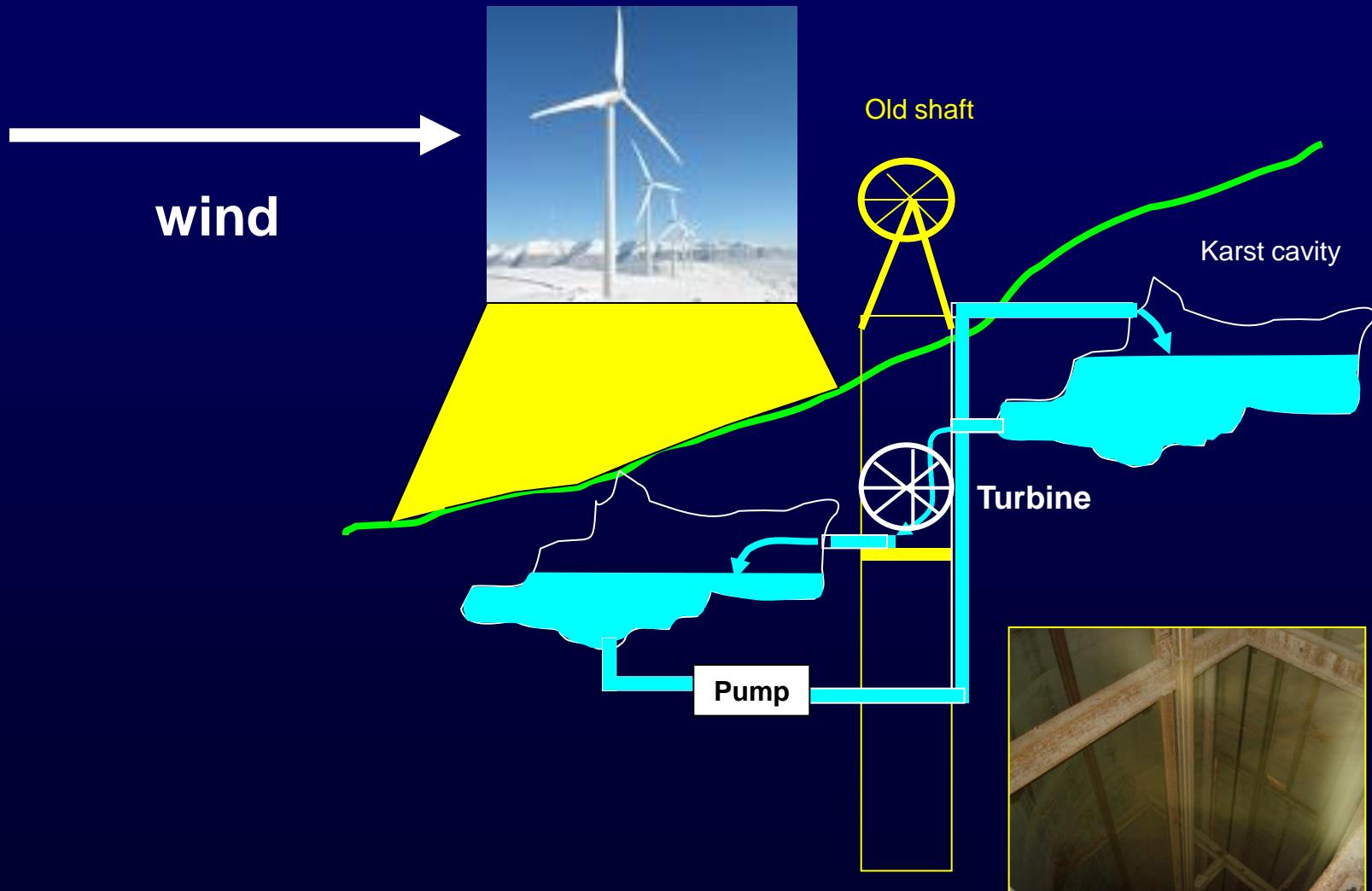
### (3) The future? Waste land transformation: wind energy



### (3) The future: Post-mining opportunities (FWR)

#### Underground hydro storage of wind energy

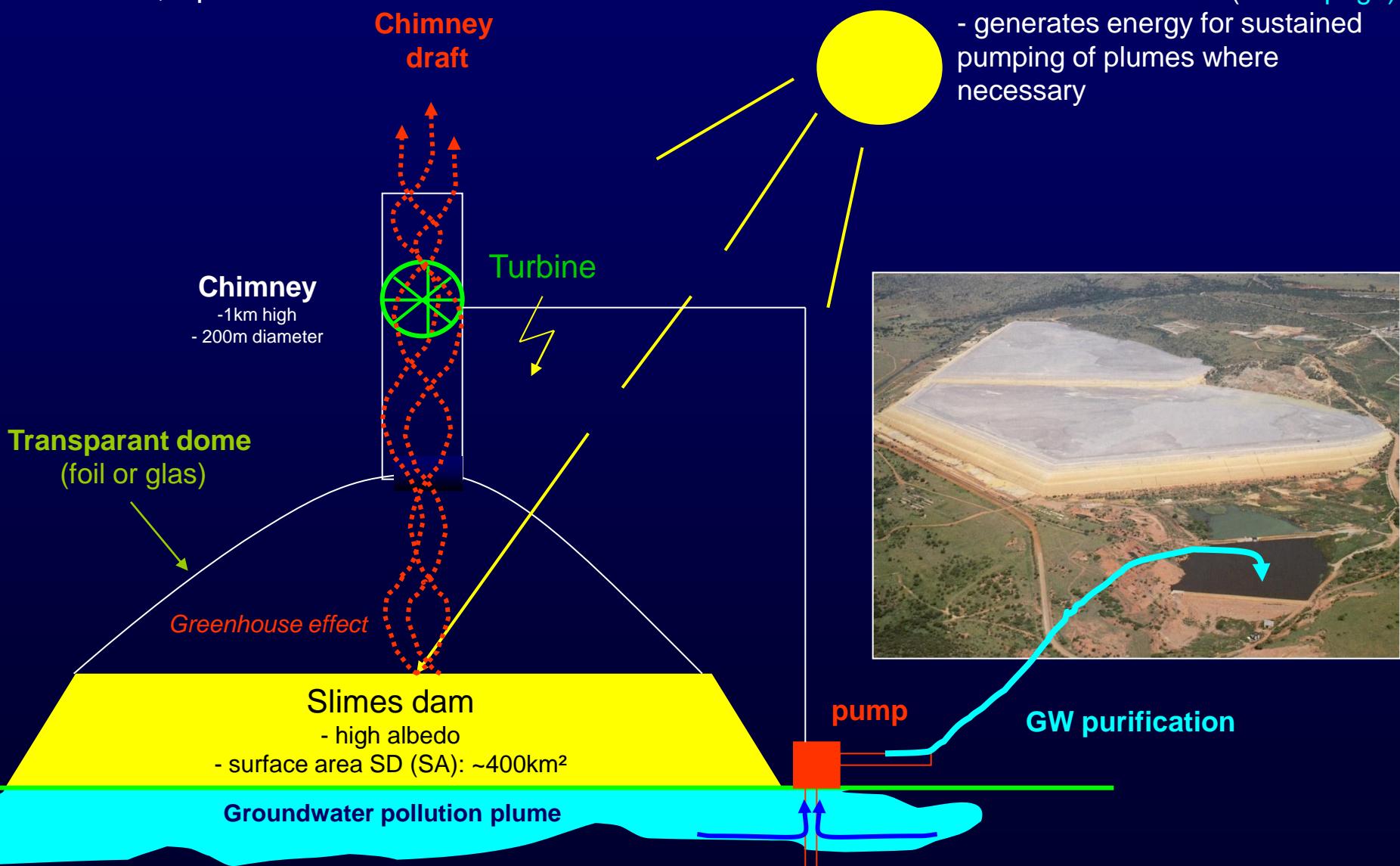
Use wind when it is available to pump water up and let it run down if energy is required



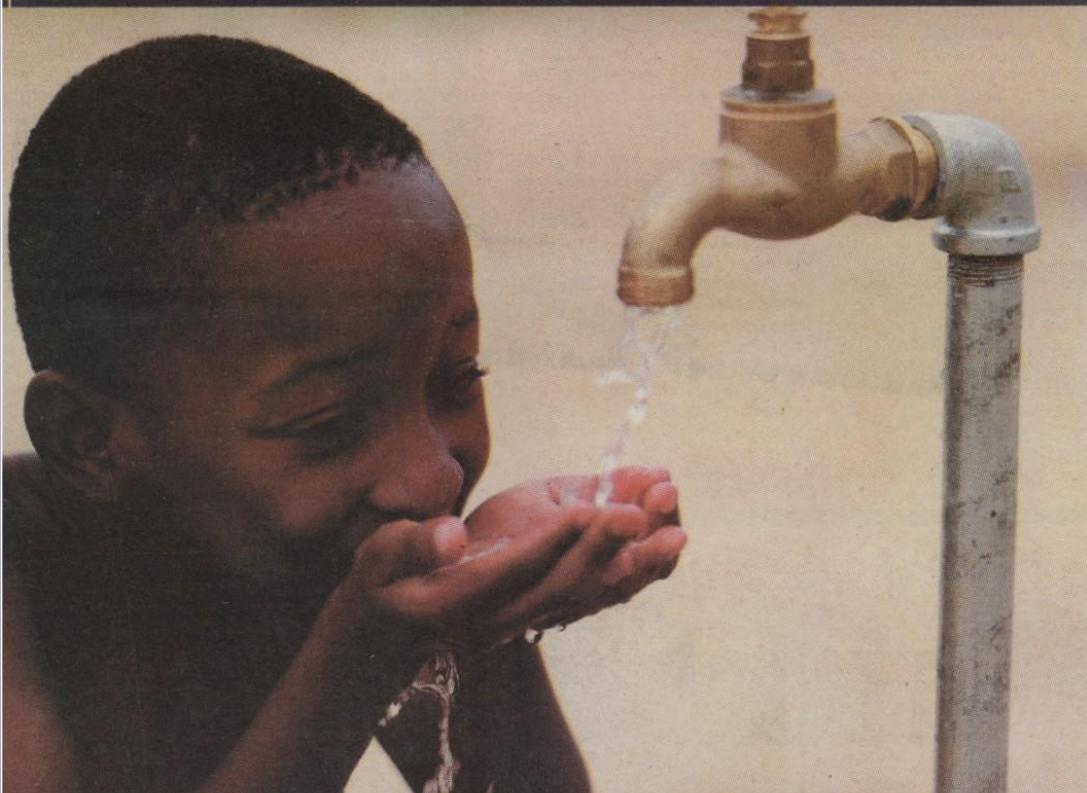
### (3) The future: Post-mining opportunities (FWR)

Waste land transformation: Solar-thermal up-wind power generation

Prototype:  
Manzanares, Spain



to grow our children



just add water



Photo: DWAF advertisement in "The Star"

Thank  
you!



[www.mwrg.co.za](http://www.mwrg.co.za)