The Nubian Sandstone Aquifer System

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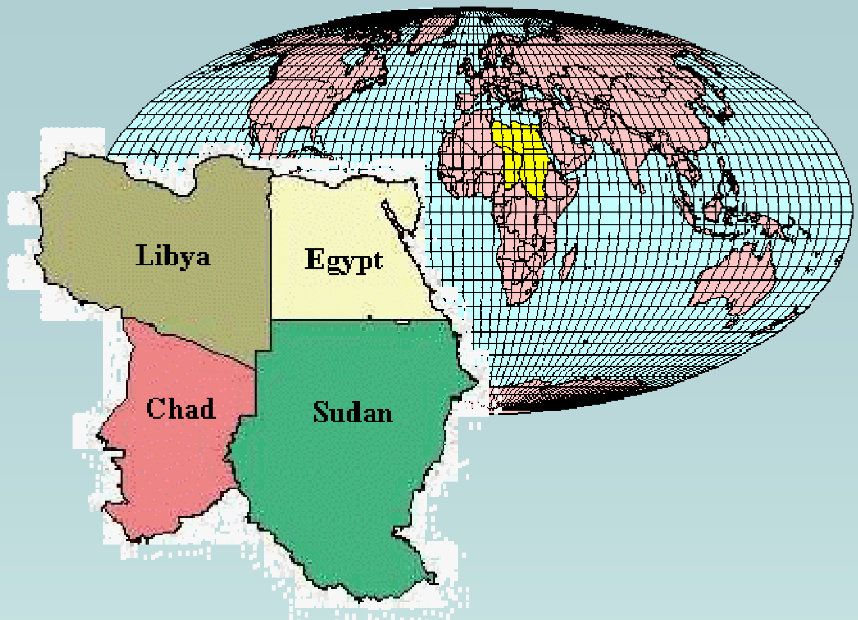
Geography



- Transboundary groundwater system beneath the north-eastern Sahara
- total extension of over 2.2 Mio km²
- Shared between four countries:

  - almost total Egypt (~80%) with an extension of 826,000km²

  - south-western Libya with an extension of 760,000km²

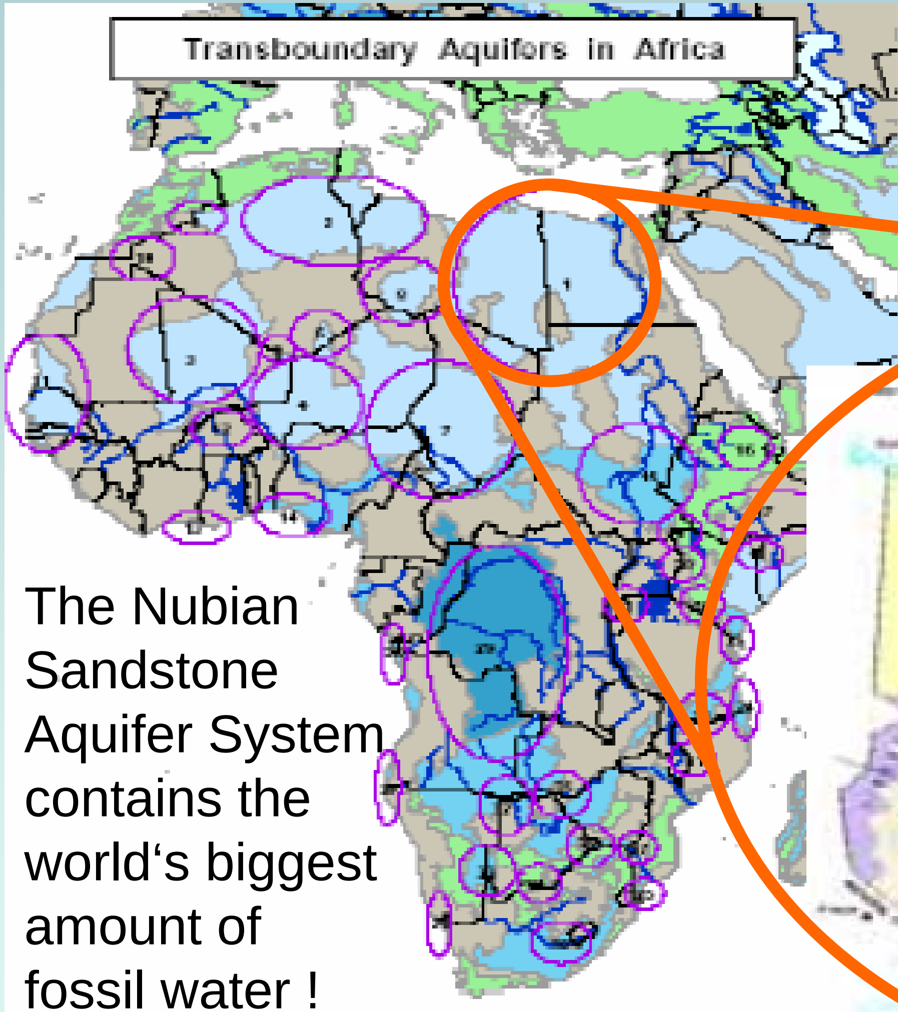
  - north-eastern Sudan with an extension of 376,000km²

  - north-western Chad with an extension of 235,000km²

- Geographical position between Latitude 14°- 33° north

  Longitude 19°- 34° east

Precise position of the Nubian Sandstone Aquifer System



Stored water volume:
150,000 km³

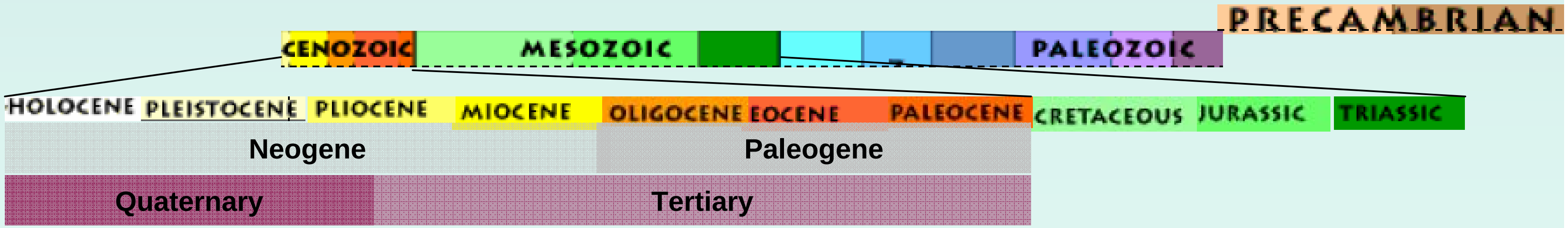
The Nubian Sandstone Aquifer System contains the world‘s biggest amount of fossil water !

Geology

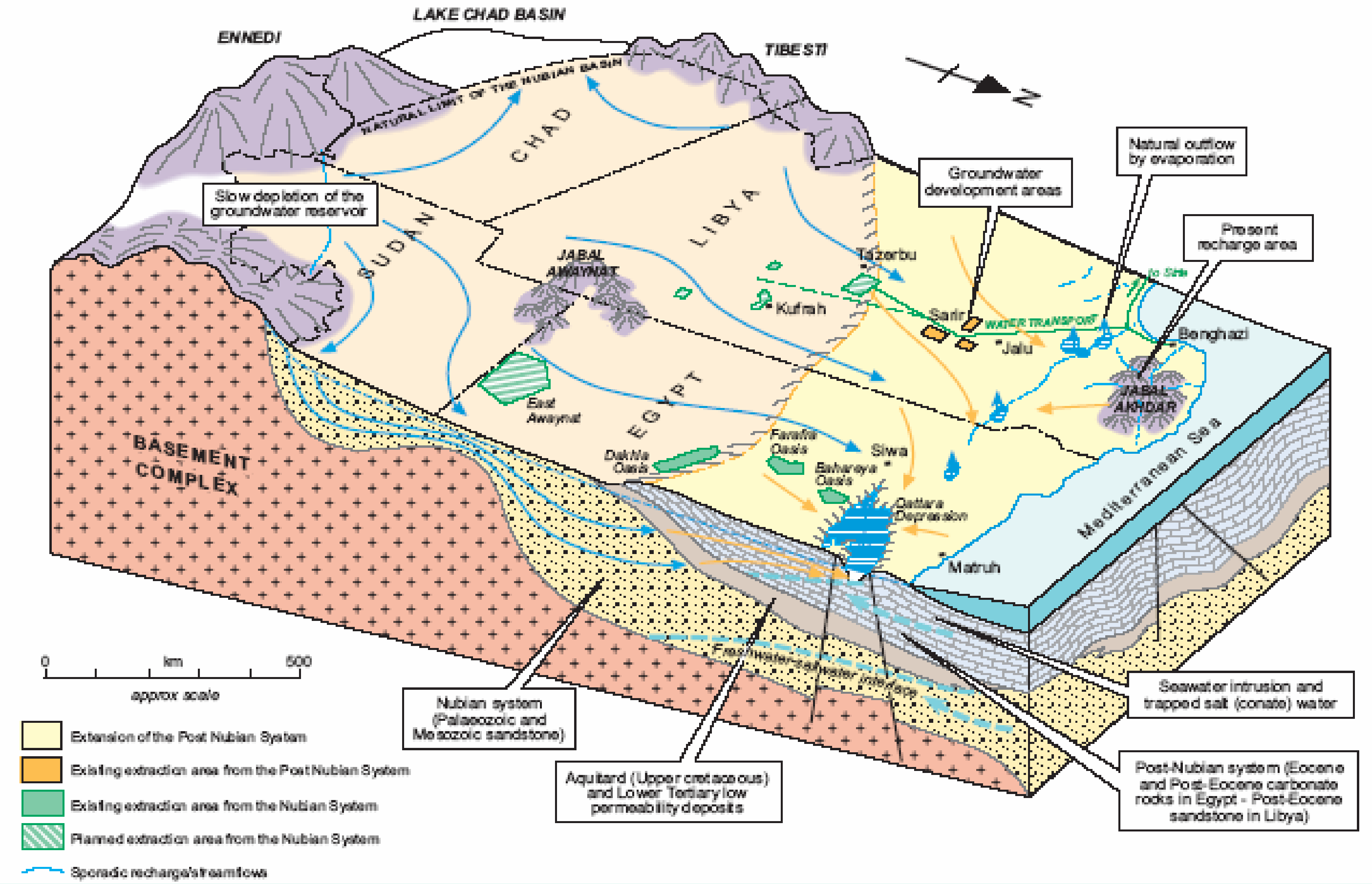
- Nubian Sandstone = flat lying to gently dipping rocks
- Made up of continental sediments including sandstones, grits, mudstones and conglomerates, overlain by alluvial deposits
- Sandstone beds with minor intercalations of siltstone and kaolintic sandstone
- Nubian Sandstones derive from Precambrian and reworked sandy Palaeozoic deposits, not altered by metamorphic processes

- Libyan part from late Jurassic to early Cretaceous
- Egyptian part from Palaeocene

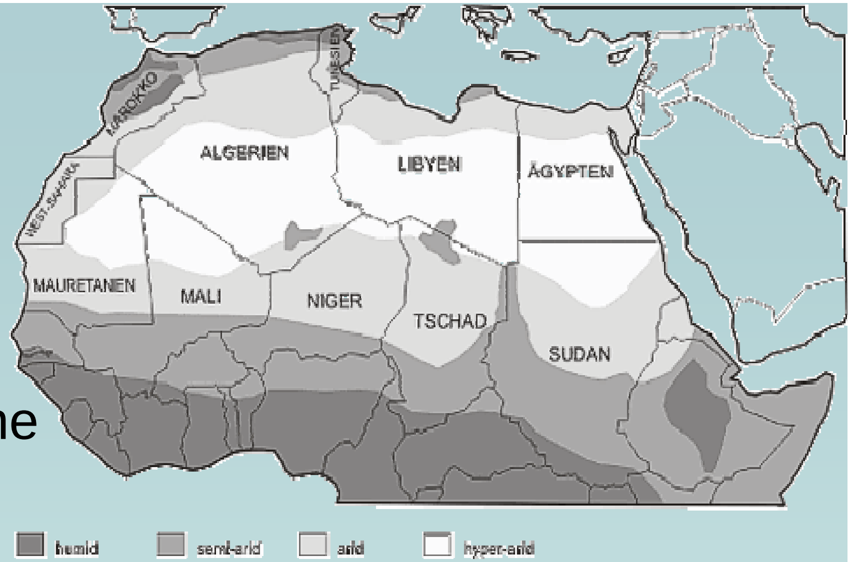
- Age of Nubian Sandstone poorly defined → doesn‘t fit into a chrono-stratigraphic system: best regarded as a purely litho-stratigraphic unit



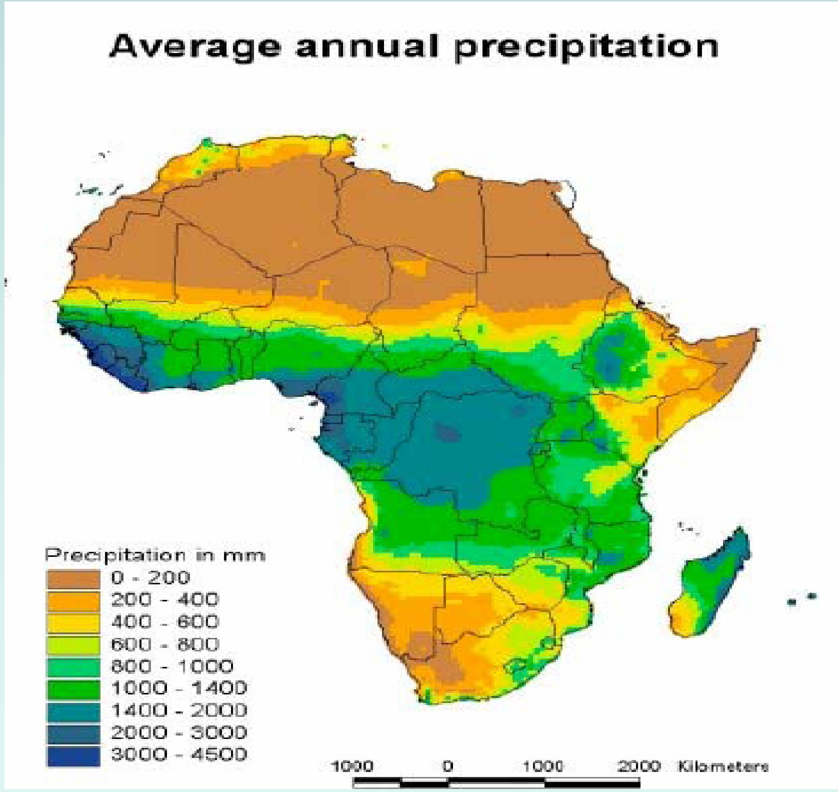
Cross - Section



Climate & Hydrology

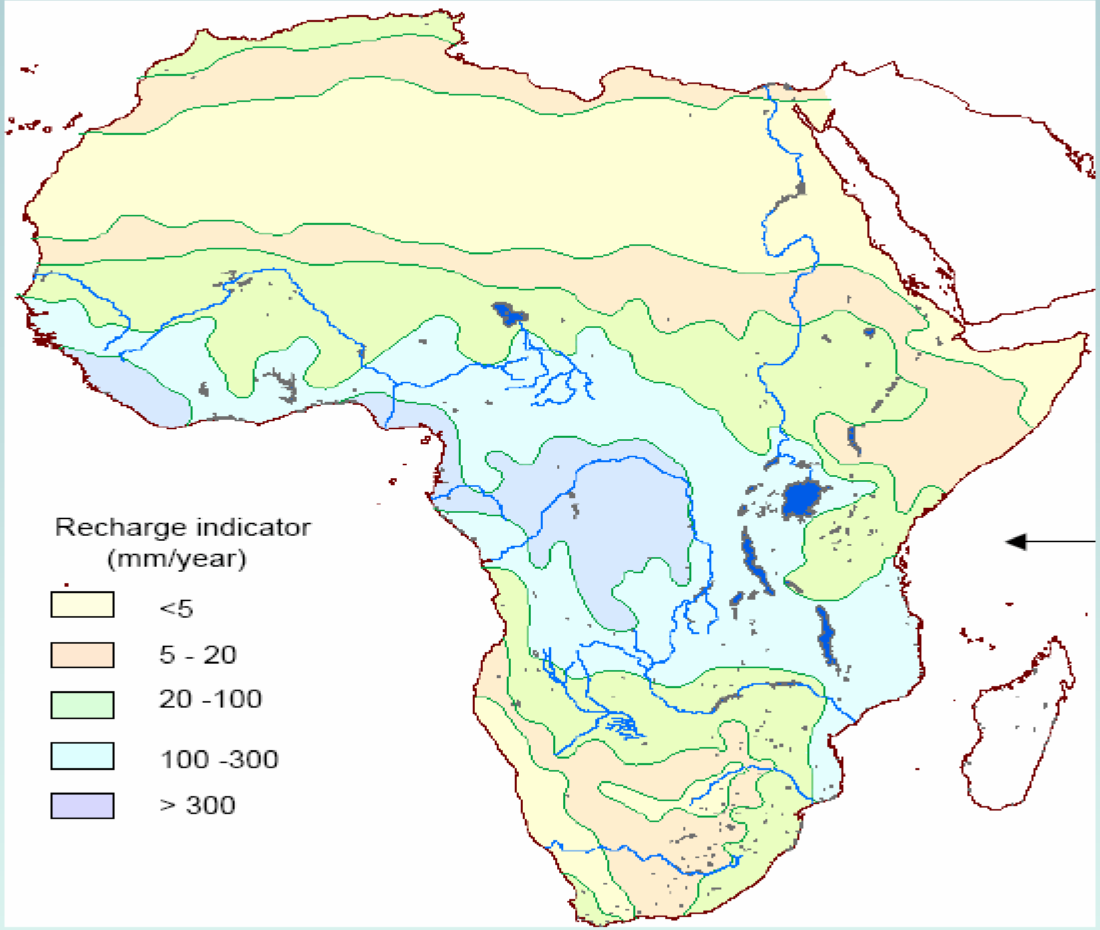


- Northern part: Mediterranean Steppe
- Middle part: great arid zone belt
- Southern part: subtropical climate zone



- Average rainfall < 5 mm/year
- Closed water system
- Age of most water > 20,000 years, partially up to 1 Mio years!
- Most groundwater is of meteoric, i.e. atmospheric origin
- very small part (juvenile water) may derive from magma

Groundwater replenishment



Main recharge sources:

- occasional rainfalls and flash floods
- groundwater flow from southern and eastern mountainous belt

→ Recent annual recharge negligible

Groundwater systems – definition of fossil aquifers

- No appreciable modern recharge, can‘t discharge naturally
- Water is stagnant with little or no flow
- Groundwater is trapped in geologic formation because of paucity of recharge
- Stored water hundreds to thousands or millions of years old

Some dates regarding the replenishment of the NSAS:

- Last recharge time at transition between Pleistocene and Holocene (late Quaternary)
- Dramatic climate changes: water stored before climate turned extremely arid

Groundwater systems

- Deep rock aquifer of sedimentary origin (sand- / limestone)
- Hydraulic gradient from the south-west to the north-east
- Basin thickness in between 500m – 3500m
- Saturated thickness in between 100m – 650m
- Transmissivity of Nubian Sandstone from 2.72 m^2/d to 72.4 m^2/d

Two principal closed drainage basins:

1) Kufra Basin of Libya, Chad and Sudan
2) Dakhla Basin of Egypt

- Multi-layered chambers hold many secrets

Groundwater systems

Two different systems because of different water bearing strata:

- *The Nubian Aquifer System (NAS):*
  - spreads over the whole area defined for the NSAS
  - medium to coarse grained sandstone
  - comprises Palaeozoic and Mesozoic deposits, overlies the Precambrian basement complex
  - lower one of the systems, over 400 m thick
  - semi-confined or partially confined aquifer

- *The Post Nubian Aquifer System (PNAS):*
  - only in the northern part down to the north of 26th latitude (Egypt & Libya)
  - comprises Tertiary continental deposits and tertiary carbonate rocks
  - sands, gravels and silts
  - upper one of the systems,10-300 m thick
  - higher permeability than NAS, unconfined aquifer

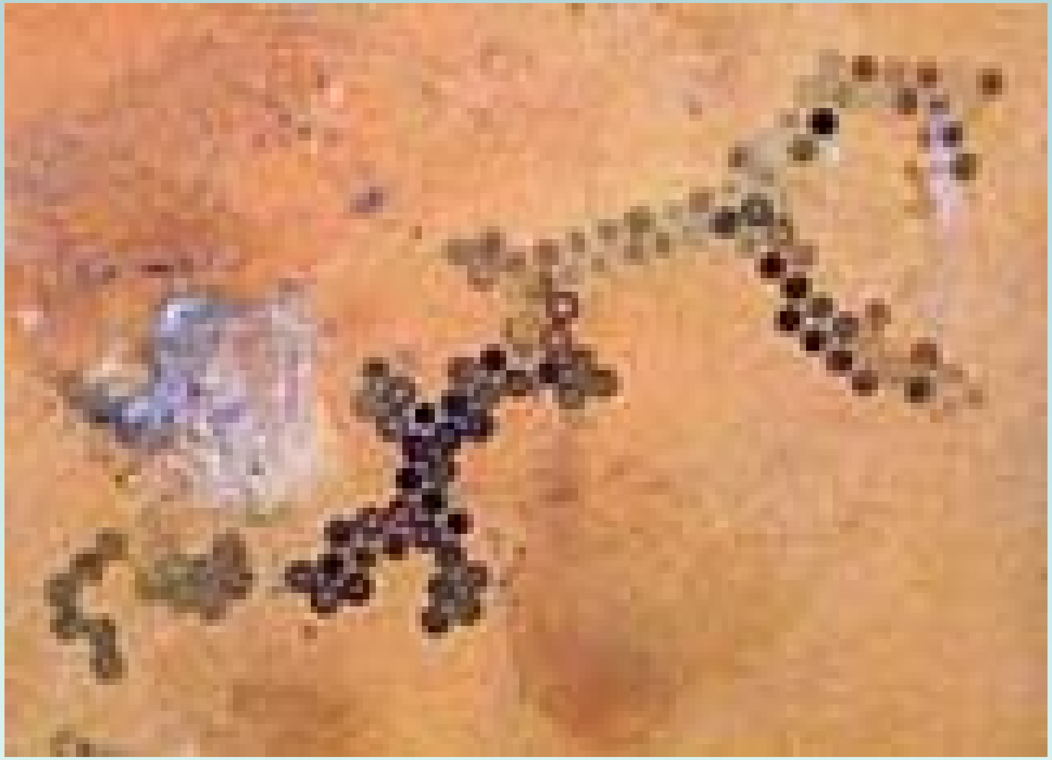
- *Separating caprock:*
  - Upper Cretaceous & lower Tertiary sediments

Groundwater use

- Hyper arid region: main use of NSAS-water for irrigation purposes and as drinking water
- Actual withdrawal rates:
  - Egypt: 1029 Mio m³/yr
  - Libya: 851 Mio m³/yr
  - Sudan: 406 Mio m³/yr
  - Chad: very low rate
- ‘Dream of blooming deserts’
- Example of agricultural use: private farms located in old traditional oasis in Egypt (New Valley)
- Example for extensive allocation: The Great Man-made River Project (GMRP) in Libya

Agriculture Groundwater Use
Al Kufrah

- Most of the NSAS water is used for irrigation
- 10.000 ha
- 750 km inland
- Mixed farming: cereals and sheep
- Production costs much higher than world price



Agriculture Groundwater Use
Al Kufrah

- Central-pivot-sprinkler with radius of 1120m.
- Huge evaporation losses
- Increase of “sustainable drawdown” from 35m to 100m !
- Drawdown is assumed to be 60m!
- Sustainable use?

The Great Man-made River Project (GMRP) of Libya

- In the mid of the 1980’s, work started on the world biggest engineering project (‘eighth wonder of the world’)
- Objective of the project: deliver water from Libya’s aquifers underlying the xeric regions to the countries big cities on the coast (Tripoli, Benghazi, Sirt)

Project subdivided into 5 phases: end of phase I inaugurated in 1991, last phase completed in 2005

The Great Man-made river project of Libya

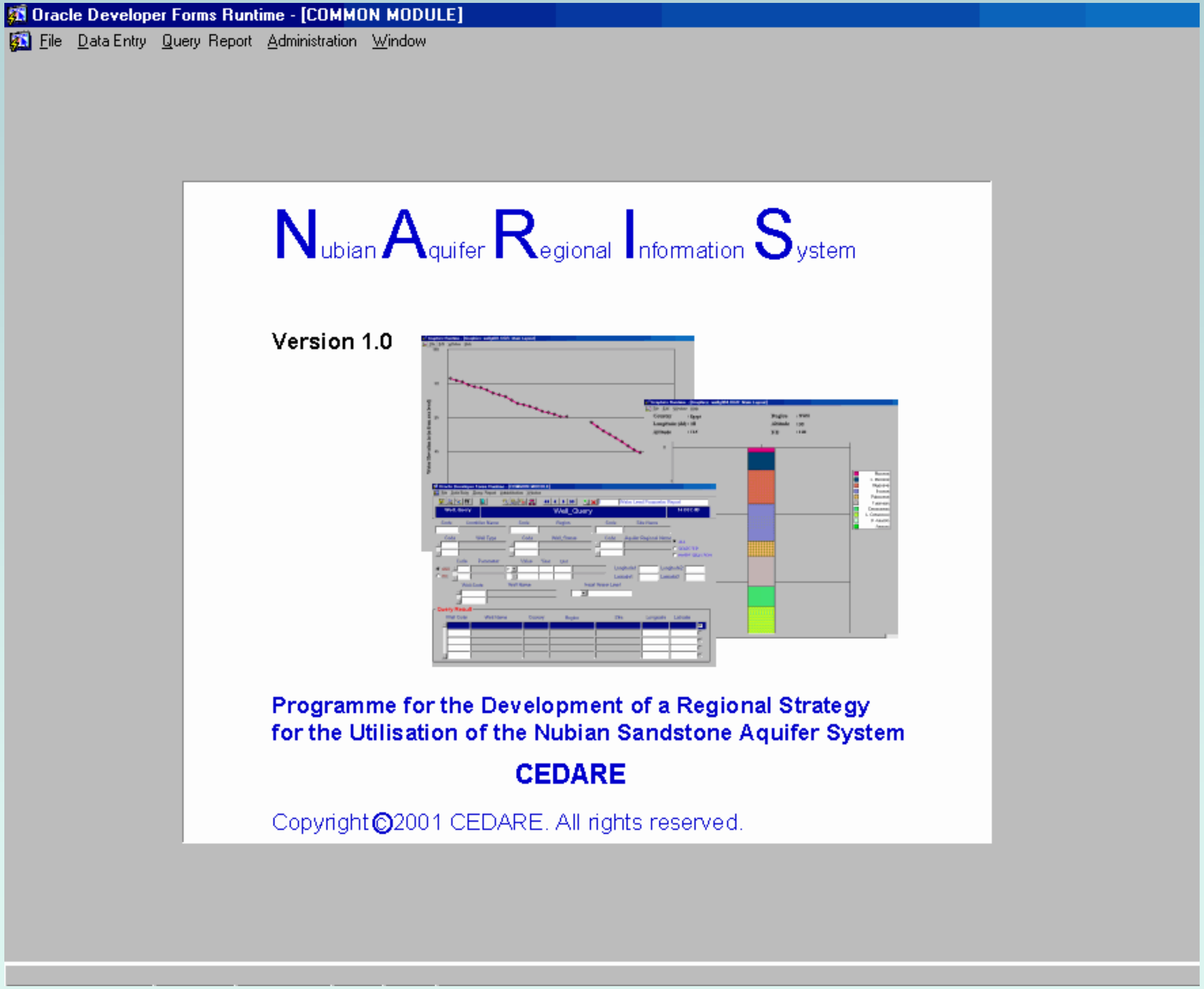
- Some facts:
  - Pipelines: in total ~ 4,000km, Ø 4m
  - Wells: ~ 3,000, depth of 450m-650m, pumping rate ~ 100 m³/day
  - Total withdrawal capacity: 6.18 Mio m³ (= 71.5 m³/s)
  - Estimated cost of total project: US$ 25 billion
  - Cost per m³: 0,35 US $ (compare desalinated seawater: > 3 US $)
  - Lowering of piezometric head after first year: 15m
  - Estimated duration until final exhaustion of the aquifers: 50 years

- Withdrawn water for municipal, industrial and agricultural use → should be enough to produce adequate water and food to meet the countries own needs
- Reduce the dependency on imports from foreign market

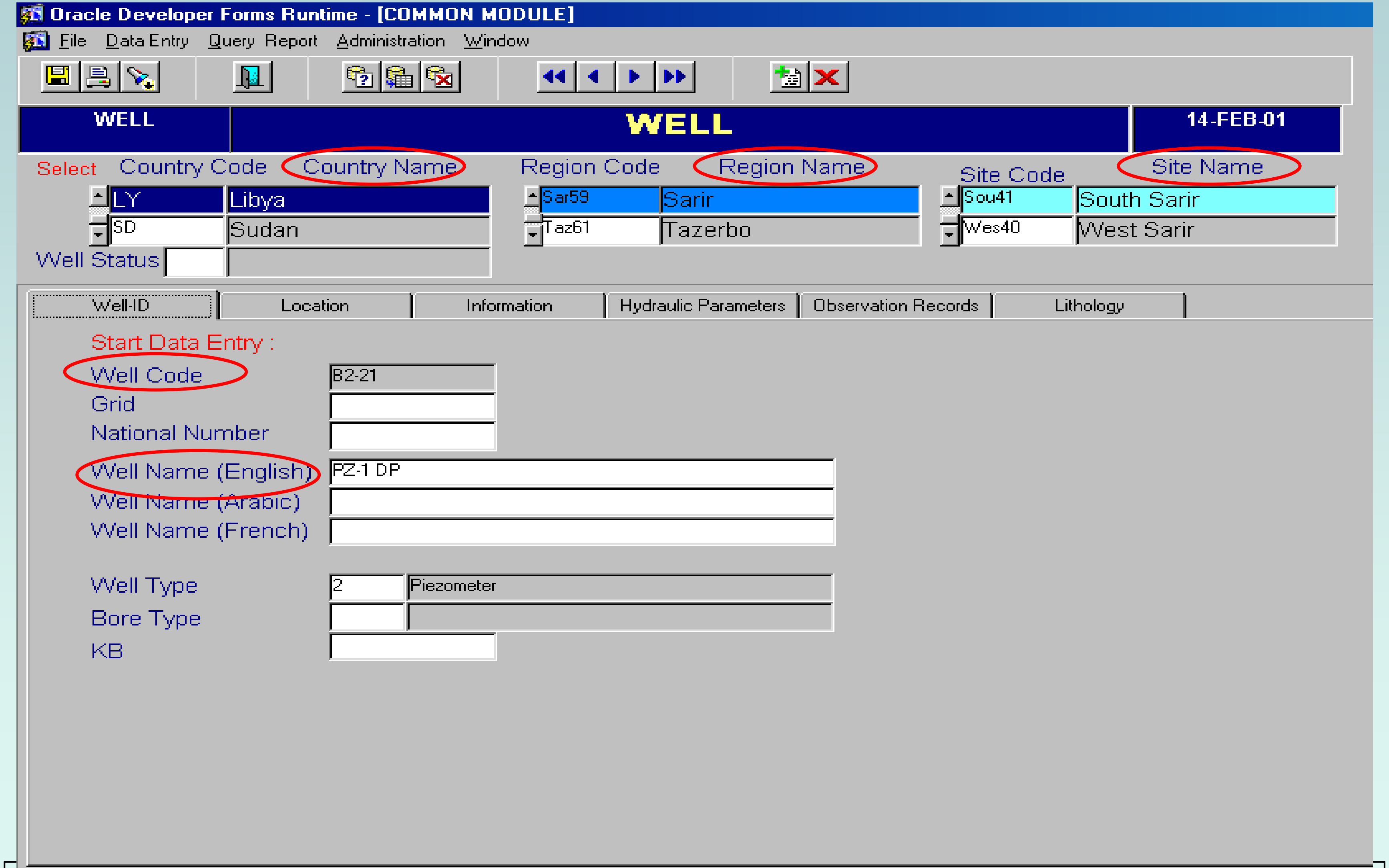
  → acceptance of high production costs and soon exhausting the source

Nubian **A**quifer **R**egional **I**nformation **S**ystem

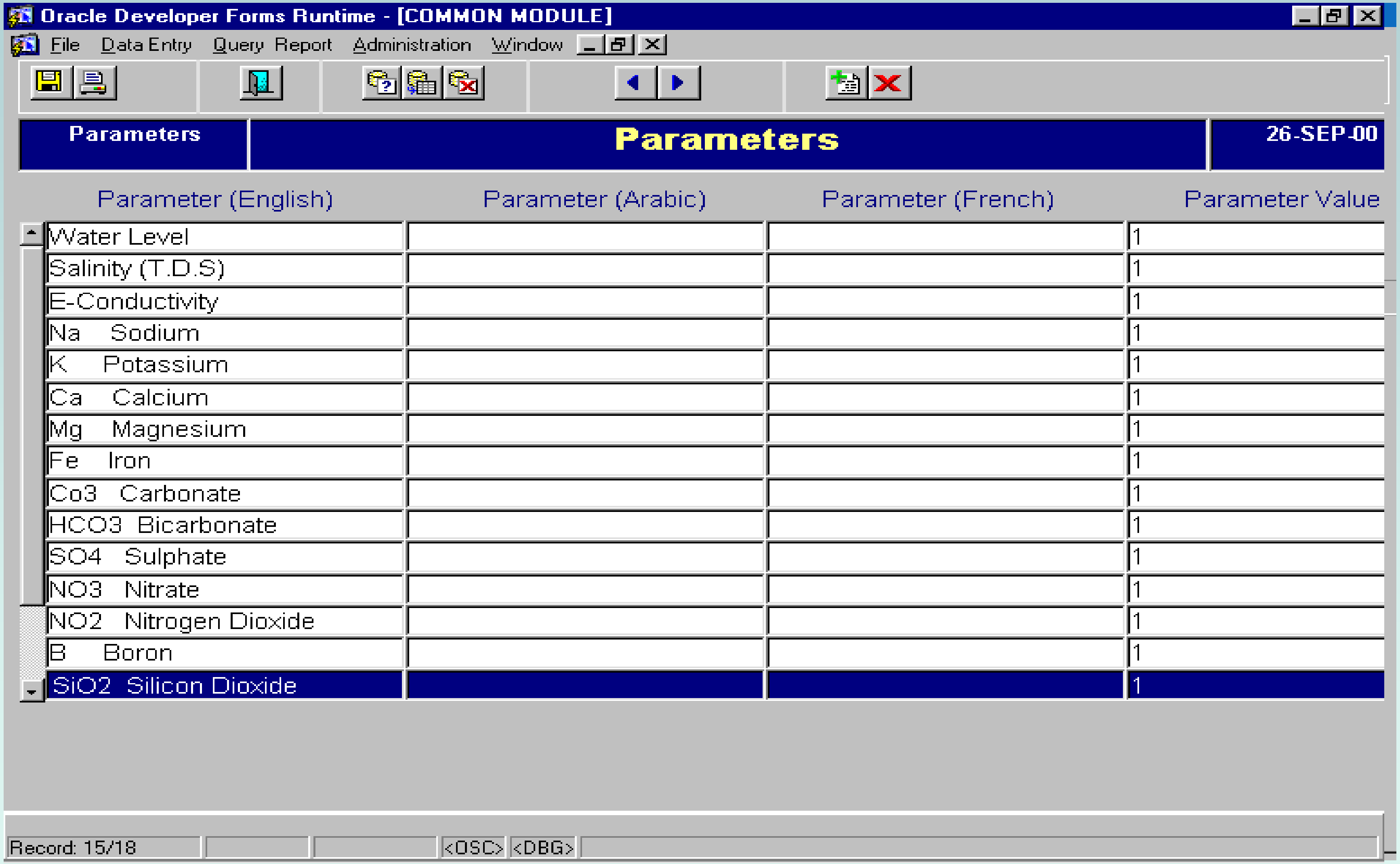
NARIS



Nubian Aquifer Regional Information System



Nubian Aquifer Regional Information System



Oracle Developer Forms Runtime - [COMMON MODULE]

File Data Entry Query Report Administration Window

Parameters | **Parameters** | 26-SEP-00

Parameter (English)	Parameter (Arabic)	Parameter (French)	Parameter Value
Water Level			1
Salinity (T.D.S)			1
E-Conductivity			1
Na Sodium			1
K Potassium			1
Ca Calcium			1
Mg Magnesium			1
Fe Iron			1
Co3 Carbonate			1
HCO3 Bicarbonate			1
SO4 Sulphate			1
NO3 Nitrate			1
NO2 Nitrogen Dioxide			1
B Boron			1
SiO2 Silicon Dioxide			1

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Transboundary Aquifers Potential or Thread?

"Although transboundary water resources can be fodder for hostility, the record of cooperation is vastly superior to that of acute conflict, that is to say, water is much more a vector of cooperation than a source of conflict."