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

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

Stored water volume: 150,000 km³
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 kaolinitic 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

[Image of a cross-section diagram showing the Nubian Sandstone Aquifer System, with labels for areas such as Chad, Ennedi, Lake Chad Basin, Sudan, Libya, and Egypt. The diagram includes symbols for slow depletion of the groundwater reservoir, natural outflow by evaporation, present recharge area, and seawater intrusion and trapped salt (conate) water.]

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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
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 m²/d to 72.4 m²/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 Aquifer Regional Information System

NARIS

Version 1.0

Programme for the Development of a Regional Strategy for the Utilisation of the Nubian Sandstone Aquifer System

CEDARE

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Nubian Aquifer Regional Information System

• Provide a standardized method for data collection and entry
• Collection of data from all wells within the Nubian Sandstone Aquifer System
• Observation of the aquifer status
• Information is retrieved either by country, region, site, well name, well code, location, tapped aquifer, date and water levels ranges
• Data will be stored on a server and accessed via internet by the four countries
• Any update of information can be viewed online by the other parties
• The System was developed in a User Friendly Interface that enables easy entry, retrieval, querying of information and production of reports
Nubian Aquifer Regional Information System

- **732 observation wells:** from the early 60s readings till the 1998 readings, including information of geographic location (longitude, latitude), total depth, elevation of measuring point, the tapped aquifer, bore type, piezometric heads.
- **1088 production wells:** information of geographic locations, ground elevations, initial water level, hydraulic parameters (hydraulic conductivity, transmissivity and storage coefficient or storativity), and quality parameters (e.g., salinity of groundwater).
- **198 exploration wells:** main source of information, with geographic locations, ground elevations, water levels, and stratigraphy.

### Table: Parameters

<table>
<thead>
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<th>Parameter (English)</th>
<th>Parameter (Arabic)</th>
<th>Parameter (French)</th>
<th>Parameter Value</th>
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“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.”