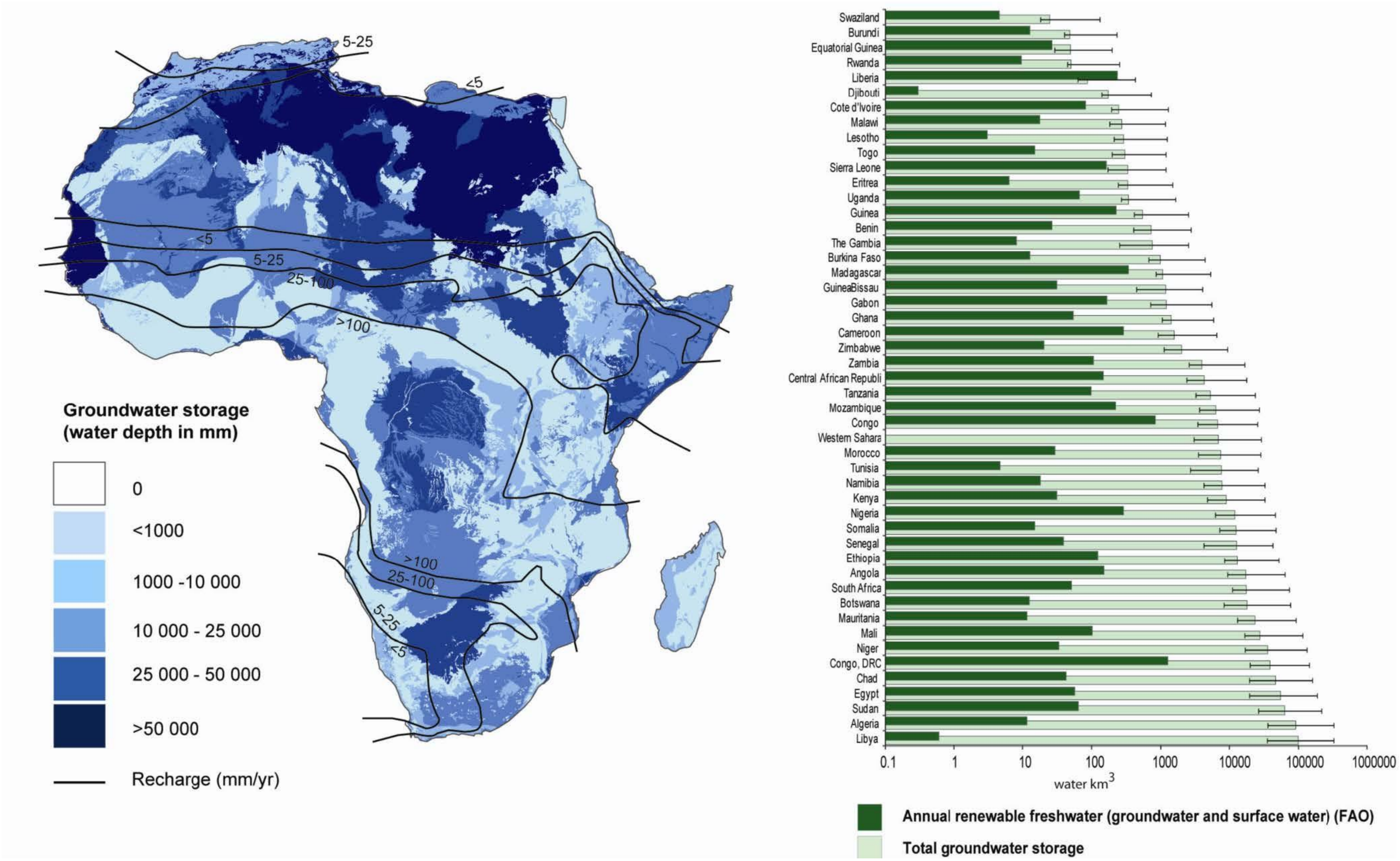
Sustainable Use of Groundwater Resources

Groundwater sustainability is the development and use of **groundwater** resources to meet current and future beneficial uses without causing unacceptable environmental or socioeconomic consequences.

(U.S. Geological Survey Circular 1186)

Groundwater is an under used resource in much of Africa (MacDonald et al. 2012)



Groundwater in Africa

Aquifers provide water for drinking and domestic use to millions of Africans.

Aquifers also provide water for irrigation of crops (about 1% of cropland in Africa is irrigated with groundwater).

Up to 1,600 km^3/year of groundwater may be available to support additional irrigation in Africa (Altchenko and Villholth, 2015)

However, prudent monitoring and management of groundwater in necessary to avoid local overexploitation and depletion of an aquifer.

Sustainability is tied to the aquifer water budget

Aquifer water budget:

$R – Q_{dis} – ET – Q_{pump} = \Delta S$

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Input – Outputs = change in storage

R is recharge, the rate at which groundwater is replenished.

Q_{dis} is flow or discharge from the aquifer to springs or streams.

ET is evapotranspiration, the extraction of groundwater by plants.

Q_{pump} is extraction of groundwater with pumps.

ΔS is change in the amount of water stored in the aquifer.

Sustainable groundwater management

Any increase in groundwater pumping by humans is balanced by some combination of:

decrease in aquifer storage, ΔS;

increase in recharge, R;

decrease in groundwater discharge to streams or springs, Q_{dis};

decrease in evapotranspiration, ET.

Sustainable use implies that the environmental and social/economic effects of these changes are acceptable.

Over pumping of groundwater can also lead to:

- Increase in power required to pump (as groundwater levels fall, more power is required for pumping)
- Land subsidence
- Change is groundwater quality or chemistry (generally a deterioration)

Change in Aquifer Storage, ΔS

Measured groundwater levels are needed to calculate the amount of water stored in an aquifer.

Rising water levels indicate an increase in water storage.

Declining water levels indicate a decrease in water storage.

The change in storage per unit surface area of aquifer, ΔS, is:

$$\Delta S = S_c \times \Delta h / \Delta t$$

where:

S_c is storage coefficient, estimated from pumping tests, and

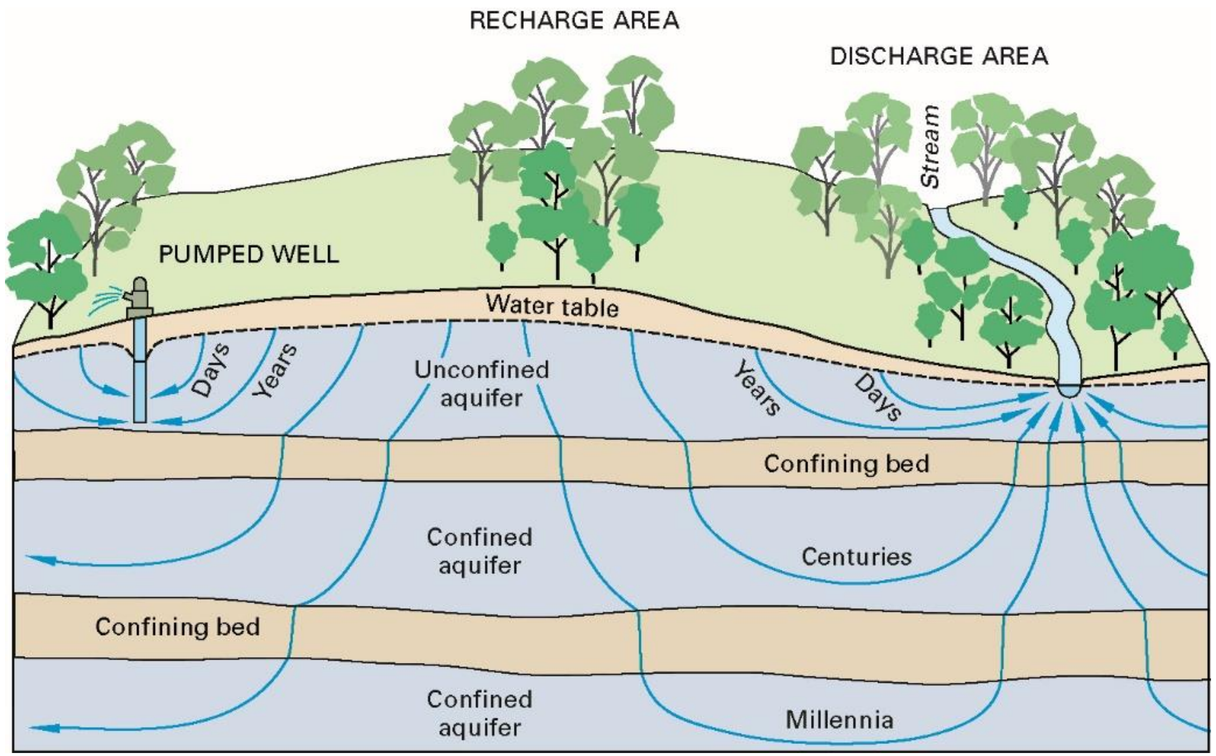
$\Delta h / \Delta t$ is the change in groundwater level (hydraulic head) over time.

Groundwater Recharge

Recharge is generated from precipitation falling on land surface above the aquifer.

Streams can also be a source of recharge.

Groundwater flowpaths vary in length and traveltime from recharge areas to wells.



Groundwater Recharge

Identification of recharge zones (areas where recharge occurs) is important:

Actions can be taken in recharge zones to enhance recharge rates (Managed Aquifer Recharge).

Recharge zones are places where groundwater is susceptible to contamination. Recharge zones should be protected from activities that may lead to water contamination.

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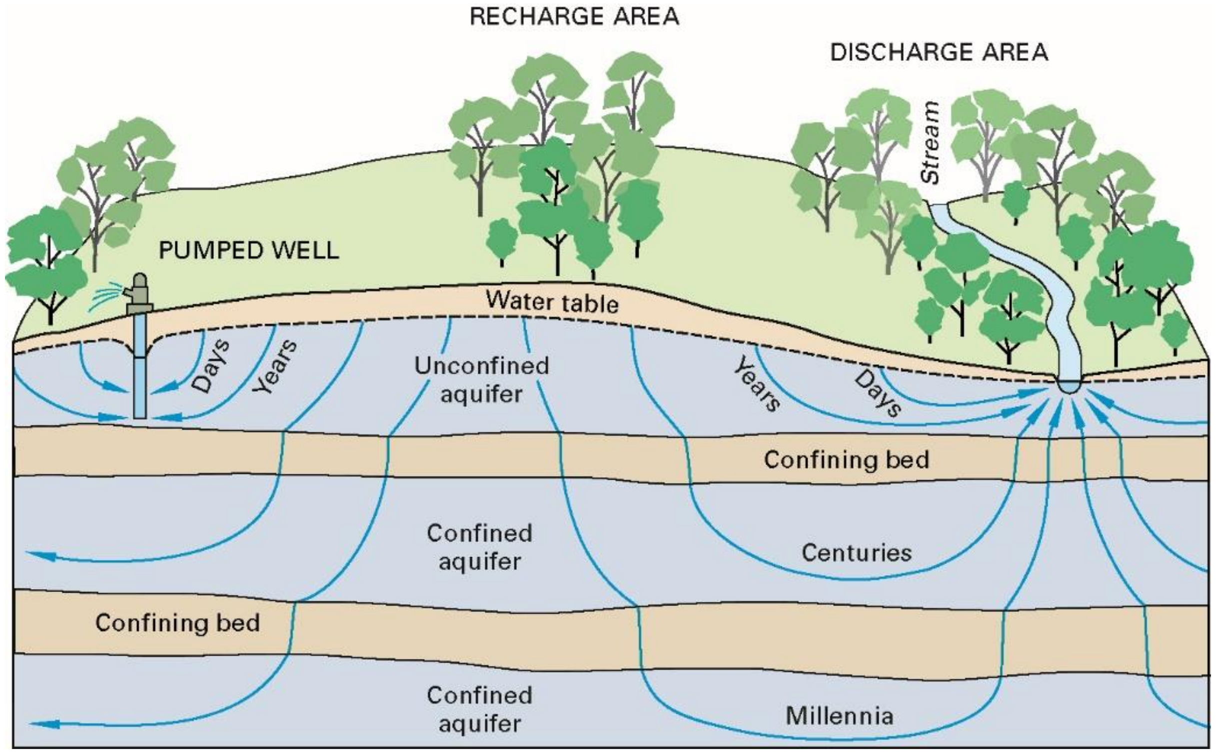


Groundwater level data has many uses:

- Determine changes in groundwater storage
- Estimate rates of recharge (short term measurements required)
- Evaluate interconnections between groundwater and streams and springs
- Calibrate computer models of groundwater flow
- Identify effects of climate change
- Determine hydraulic properties of aquifer (as part of pumping test)

Monitoring of Groundwater Levels to Assess Sustainability of Management Practices

Example – Potato farming region in South Africa.

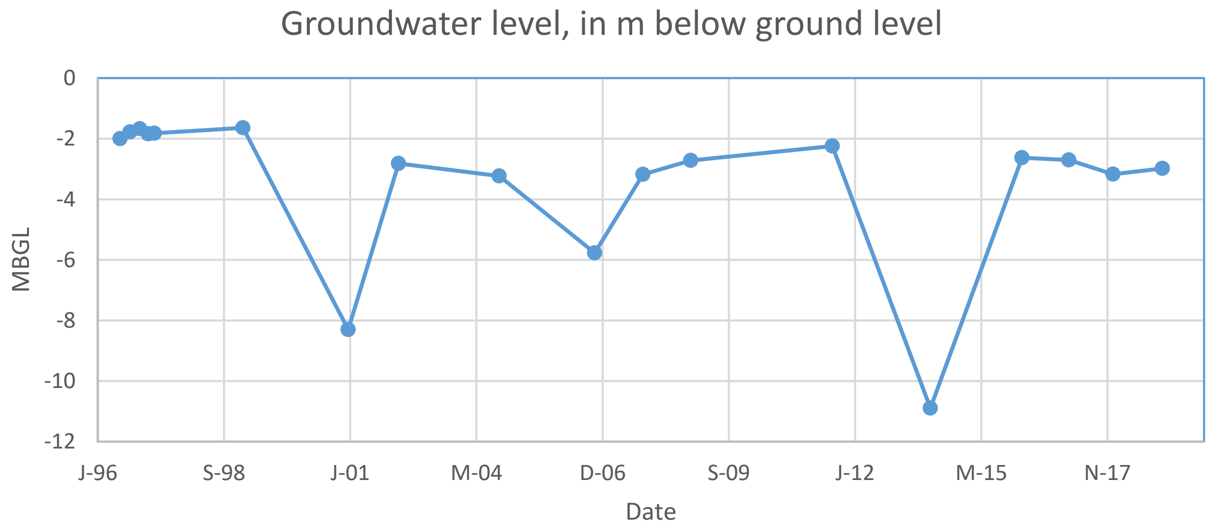
Two monitoring wells: A and B

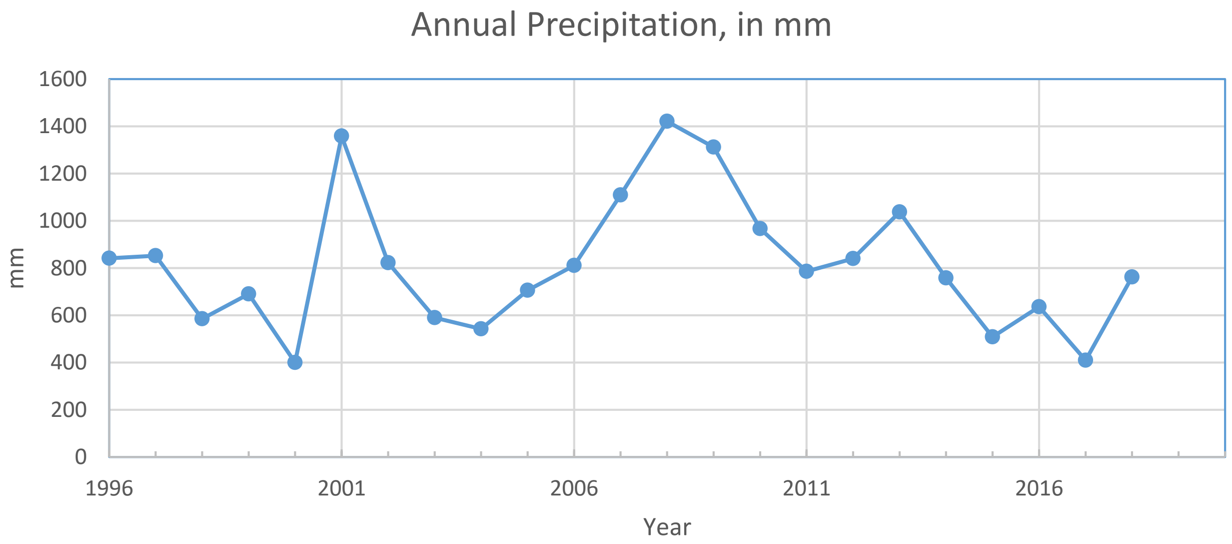
Site A – South Africa

Groundwater levels and rainfall measured.

Water levels fluctuate over time in response to rainfall, but overall the groundwater level remains relatively stable over 21 years of pumping.

This appears to indicate ***sustainable*** water management practices. That is, there are no apparent adverse effects from pumping.

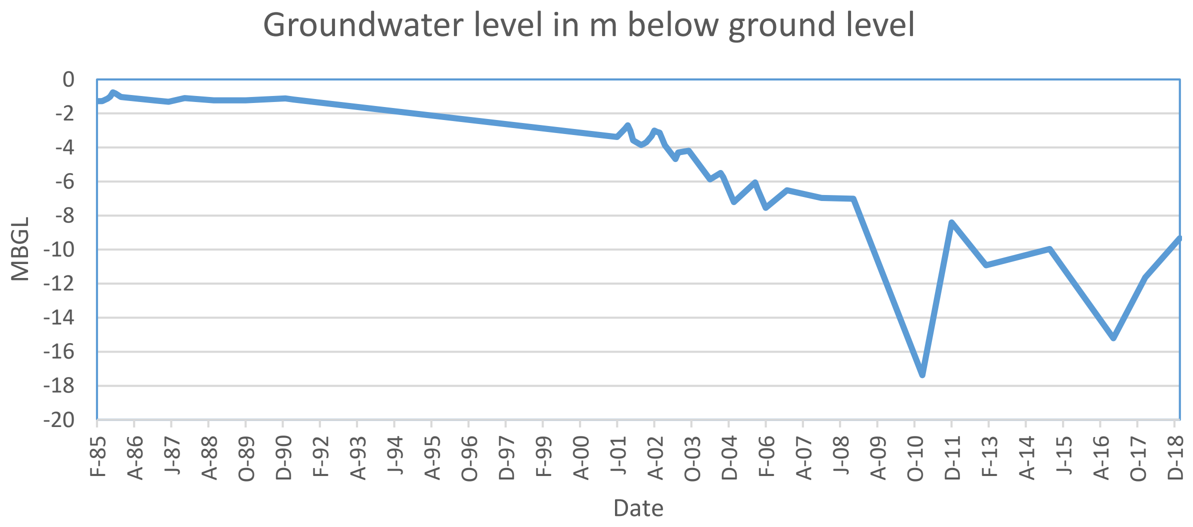


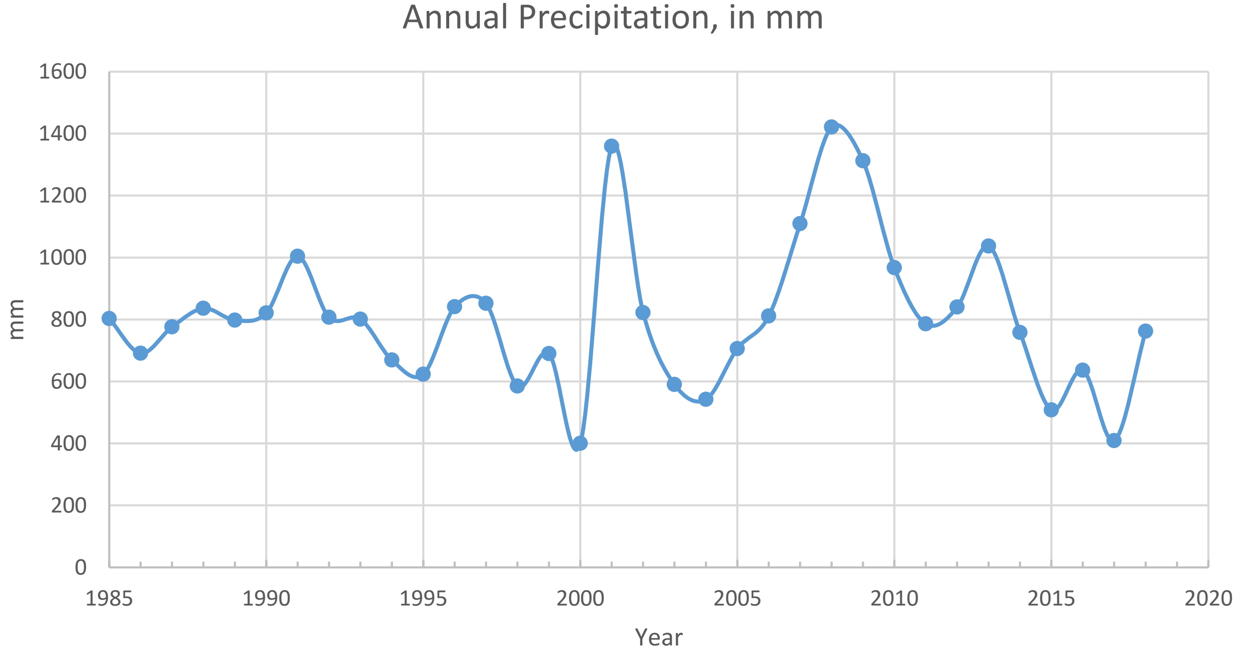


Site B – South Africa

Groundwater levels, rainfall, and electrical conductivity (EC) of groundwater were measured.

Groundwater levels show a general trend of decline over the 33 years of observation. Steep declines are associated with low rainfall years. Water levels recover somewhat in wetter years, but the overall trend is downward.

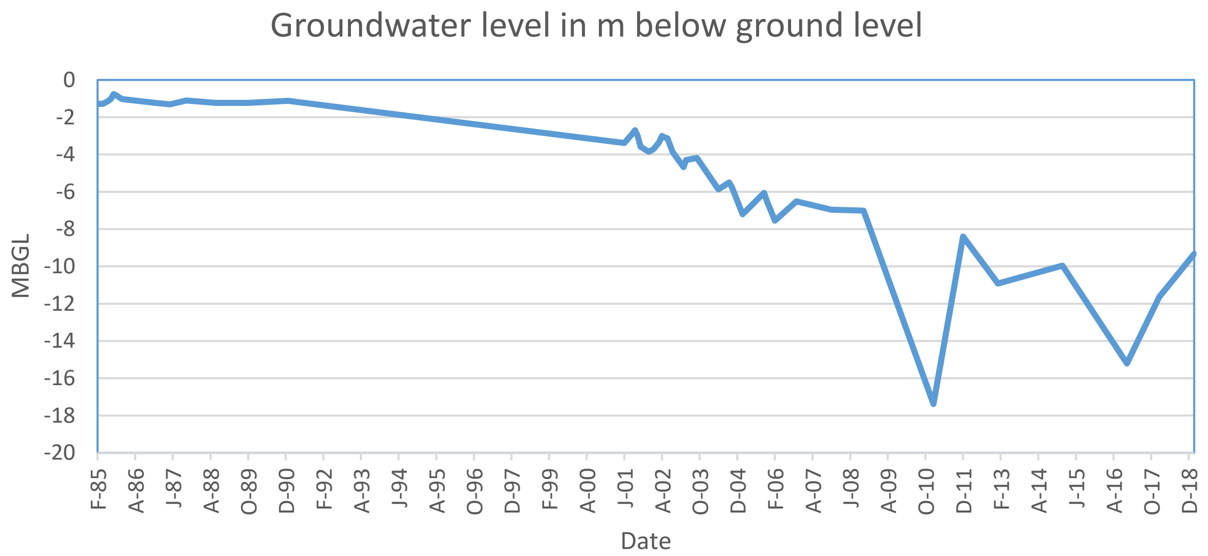


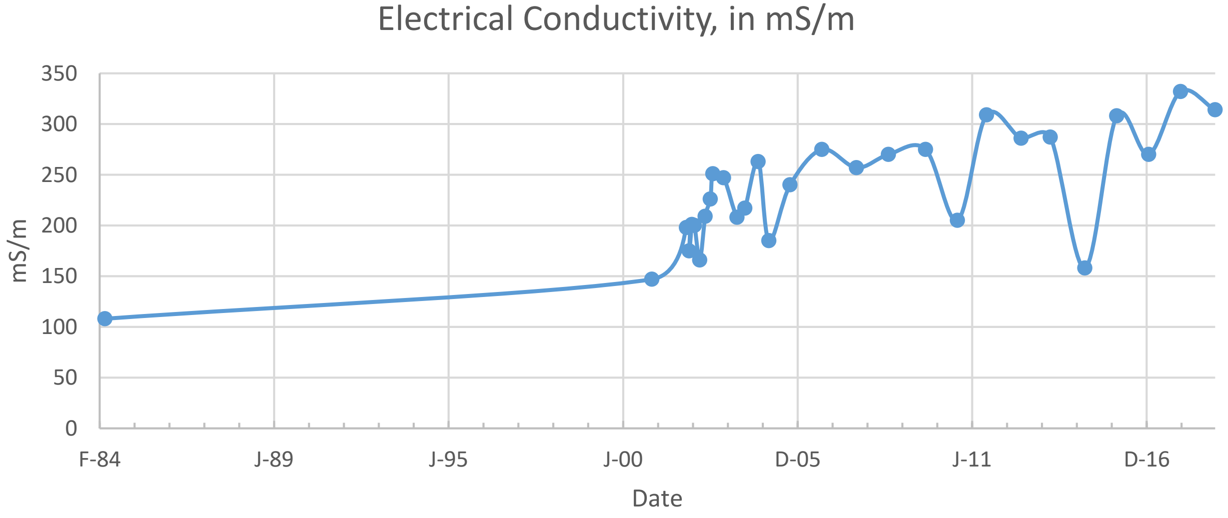


Site B – South Africa

As groundwater levels decline, the electric conductivity of groundwater increases – in other words, the quality of the water decreases.

Continuation of current aquifer management practices is ***unsustainable*** – if practices are not modified, eventually the aquifer will be depleted or the reduced quality of water will limit its use.





Site B – South Africa

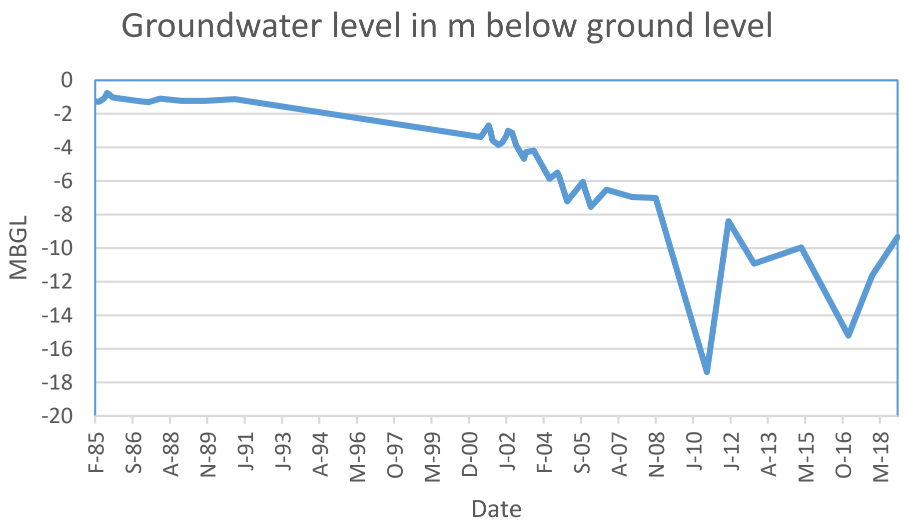
Sustainable use of this aquifer will require modification to management practices, most likely involving:

reduction in pumping rate

and/or

enhancement of recharge

(Managed Aquifer Recharge)



Summary – Sustainable Use of Groundwater

- Sustainable management ensures a long-term water supply.
- Unsustainable use can lead to aquifer depletion, reduced flow to streams and springs, increased pumping costs, and deterioration of water quality. In the worst case, a total loss of this resource.

Summary – Sustainable Use of Groundwater

- The best way to monitor sustainability is with a data-collection program with measurements of:

  Groundwater levels

  Pumping rates

  Precipitation rates

  Electrical conductivity or other water quality indicator
- Identifying recharge zones may allow enhancement of recharge rates.
- Activities that can lead to water contamination should be restricted in recharge zones to protect groundwater quality.
- Groundwater flow models are useful tools for assessing sustainability.