Impact of climate change and human activities on groundwater resources in Kenya:

(Current knowledge and initial findings in Nairobi aquifer system, a strategic aquifer under high pressure.)

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Rationale

- **Interest:** Impact of climate change and Human development on groundwater resources in East Africa (**Kenyan case: Nairobi volcanic aquifer suite**)

- **The Big Question:** With the increasing groundwater demand, infrastructure development and climate change impact: **Is Nairobi groundwater exploitation sustainable**?

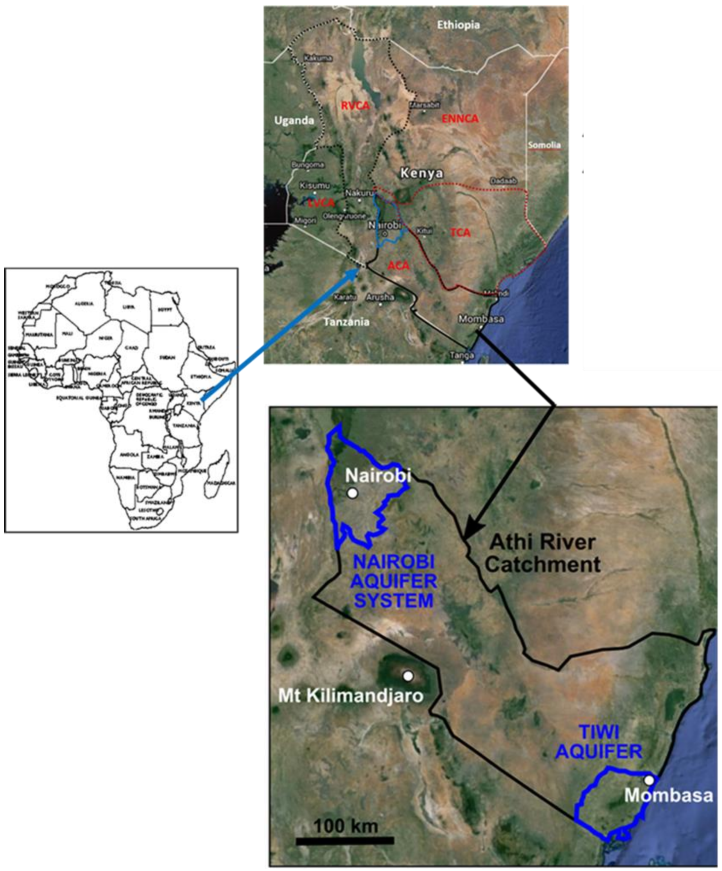
- **Overall research aim:** To establish the response of Nairobi aquifer systems to climatic change and human development.

- **The specific aim:** To establish a robust conceptual understanding of the properties and external drivers of the Nairobi aquifers and to provide new constraints for the groundwater simulation models.

Outline

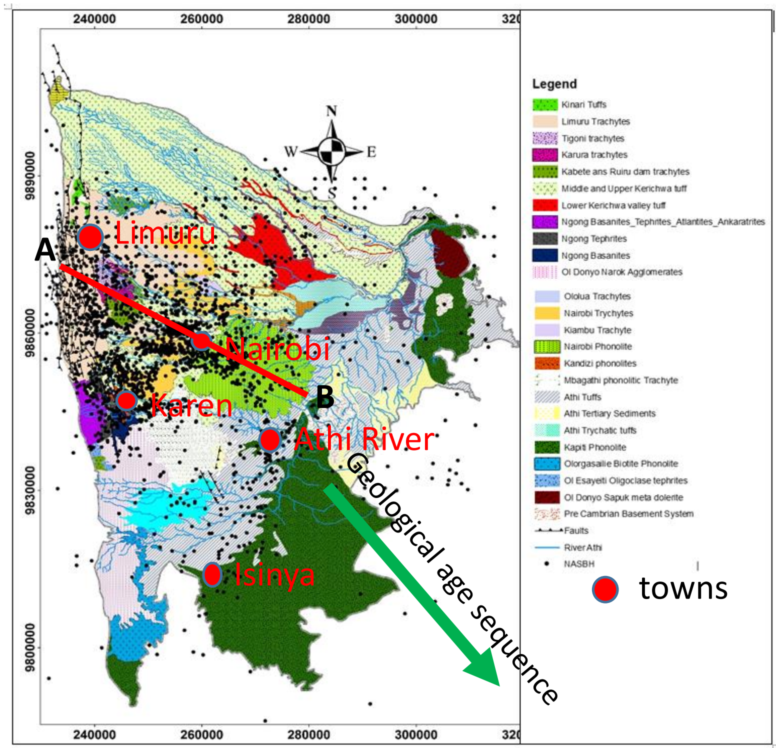
- Introduction
- Methodology
- Results/discussions
- Conclusions
- Future work
- Acknowledgement

Introduction



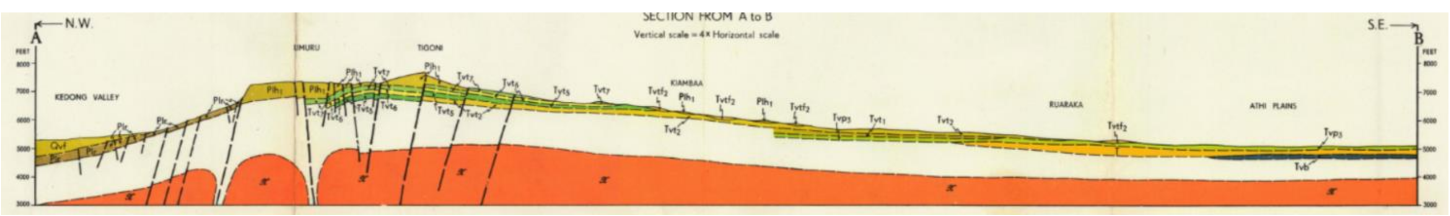
- Geographical location: 0° 37‘ 58'‘ to 1° 59‘ 23''South and 36° 34‘ 27'‘ to 37° 28‘ 17'‘ East
- Altitude ranges from 1500 m to 2600 m
- Annual rainfall of 1000 mm (classified as humid)
- Subtropical highland climate with annual temperature of 10°C and 25°C
- Regional commercial, diplomatic and industrial hub in East and Central Africa
- Population growth rate of 4.1% (2009 census)

Geology of the Area



- Rift system
- Volcanic suite (Pleistocene & Tertiary)
- 75m – 400 +m thickness
- Major aquifer
- Athi Lake sediments and Tuffs
- Crystalline basement minor aquifer (low yield/permeability)

Epoch	Symbol	Name	Group
Pleistocene	Plh1	Limuru trachytes	Upper division
	Tvt7	Tigoni trachytes	
	Tvt6	Karura trachytes	Middle division
	Tvt5	Kabete trachytes	
	Tvt2	Nairobi trachytes	
Tertiary	Tvt1	Kiambu trachytes	
	Tvp3	Nairobi phonolites	Lower division
	T	Athi tuffs & lake beds	
	Tvb	Simbara basalts	
	Tvp1	Kapiti phonolites	
Pre-Cambrian	$\mathcal{X}$	Cystalline Basement rock	

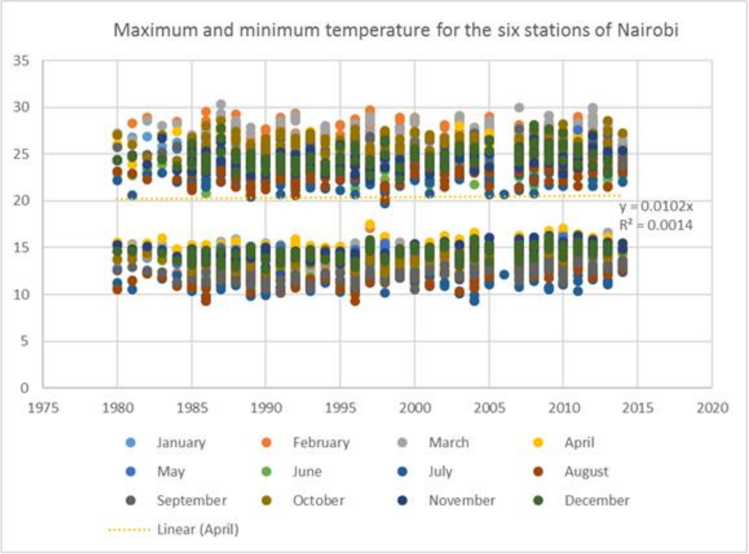


Methodology

- Data mining & synthesis (hydrogeological and climatic)
- Land-use change and groundwater abstraction evaluation
- Hydrochemistry (basic in-situ measurements)
- Oxygen & Hydrogen isotopes analysis
- Geophysical investigations (Electrical Resistivity Tomography)

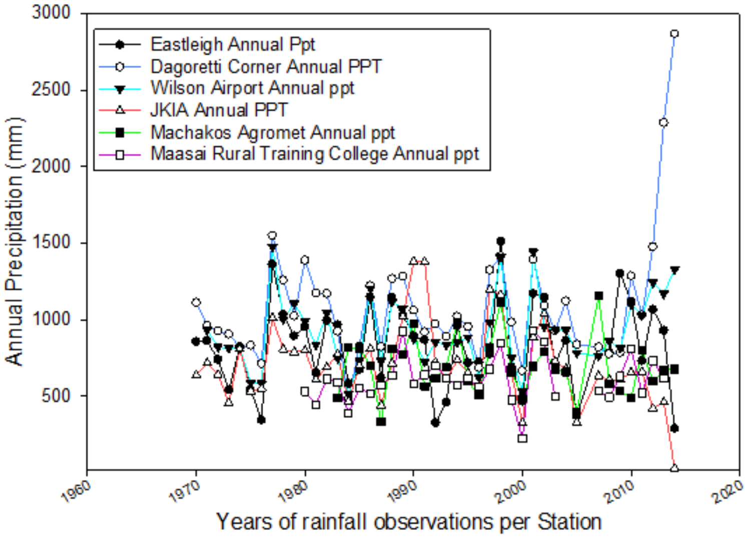
Results/discussions

Climatic Pattern of Nairobi Over a period of 30Yrs



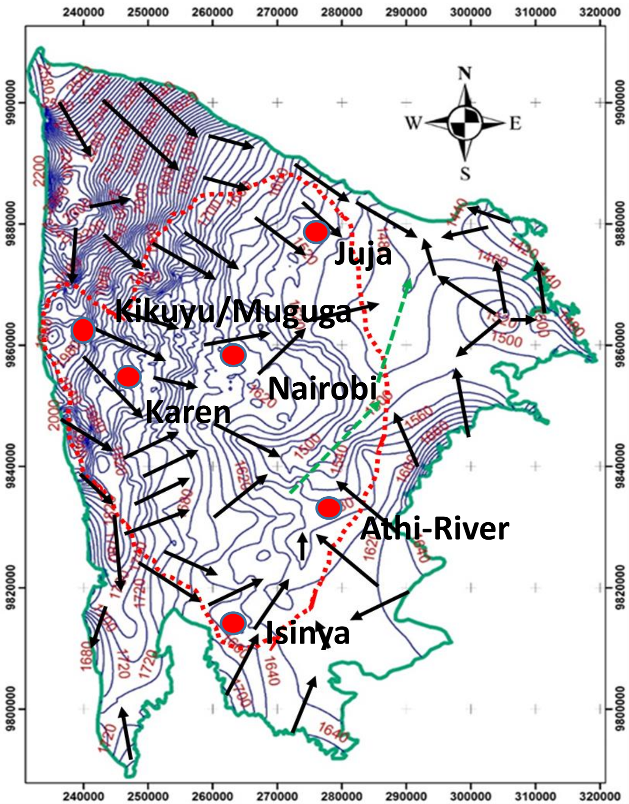
Temperature is increasing by a factor of 0.0102 °C/year

Annual precipitation of several Stations in Nairobi Observed over 40 yrs

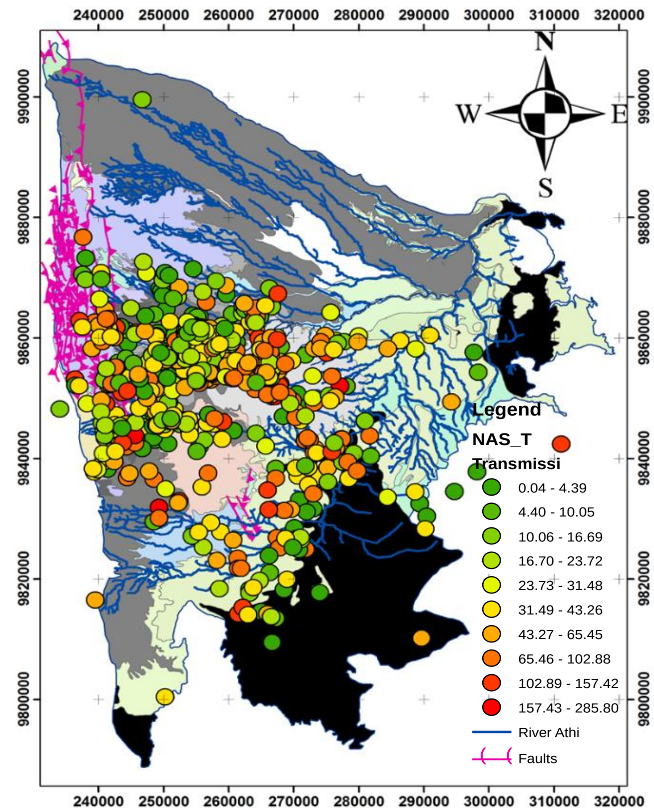


Rainfall is increasing by a factor of 0.425 mm/year

Hydrogeology of the Area



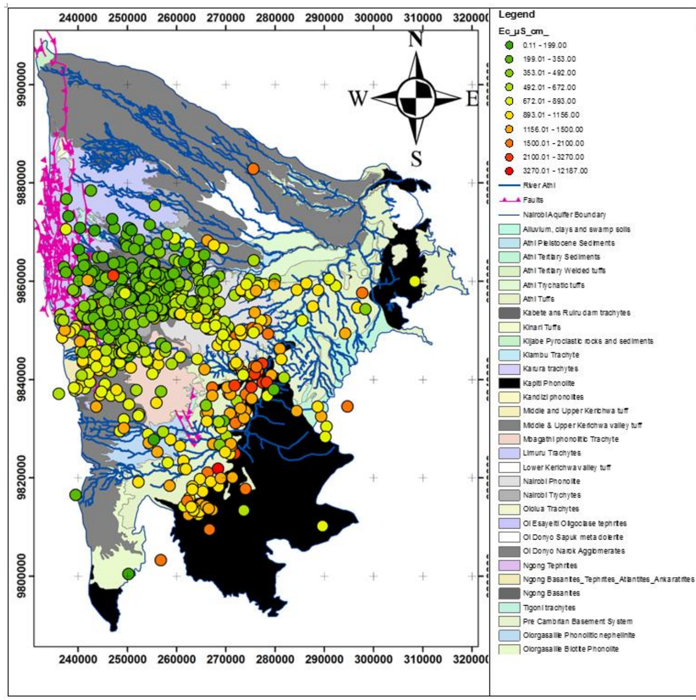
Potentiometric surface and flow lines of Nairobi Aquifer Suite



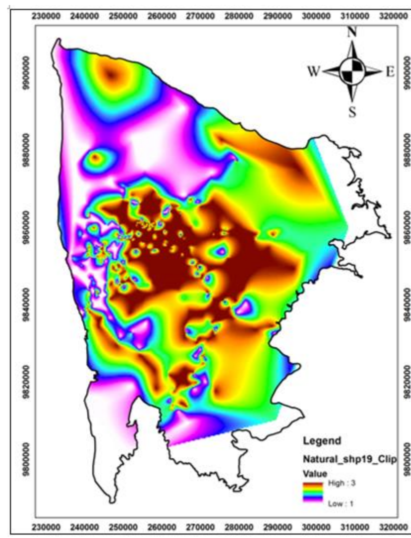
Transmissivity over geology

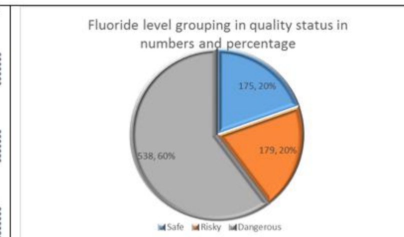
Groundwater Quality of the Area

- EC values are controlled by geological formation and groundwater resident time.
- Almost over 80% of observed wells have fluoride levels above recommended WHO standard



Electrical Conductivity overlying geological units

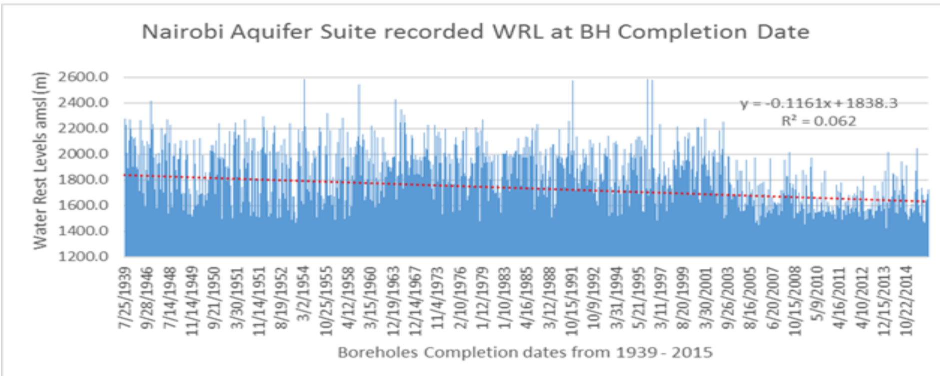




Fluoride distribution

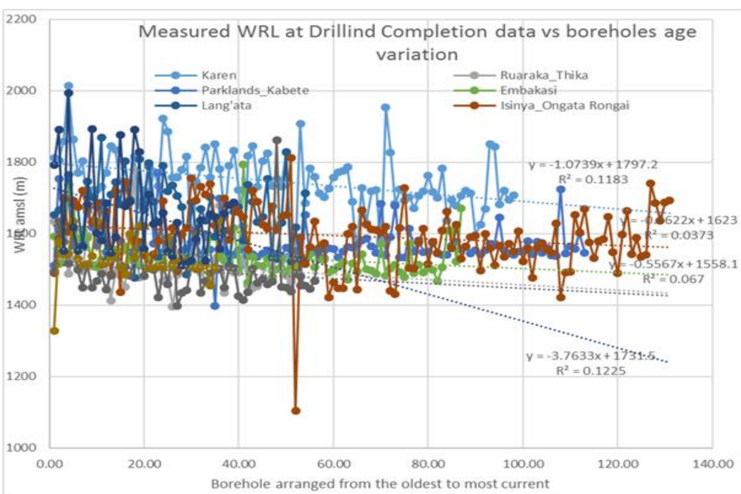
Safe	Risky	Dangerous	Total
175	179	538	892
19.7	20.2	60.1	100%
0 - 1.5	1.51 - 3.99	>4	Group range
1	2	3	Quality Group

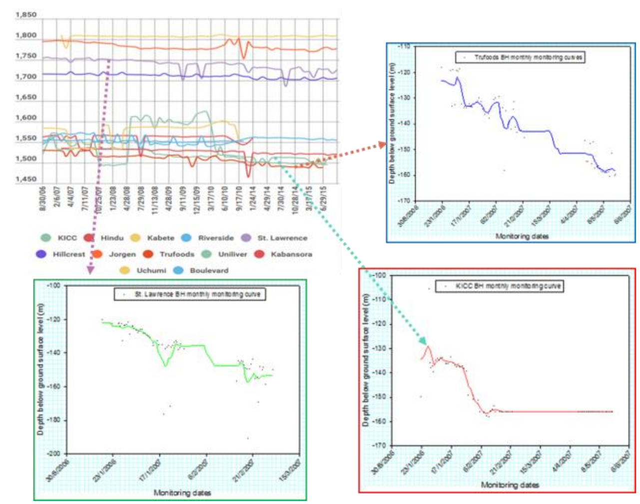
Groundwater level evolution of the Area



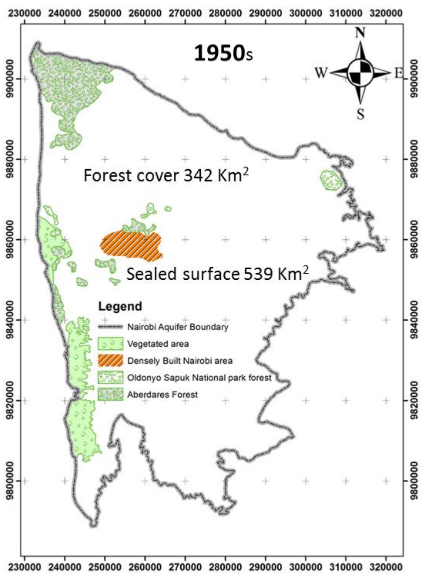
- GW level evolution from borehole completion reports

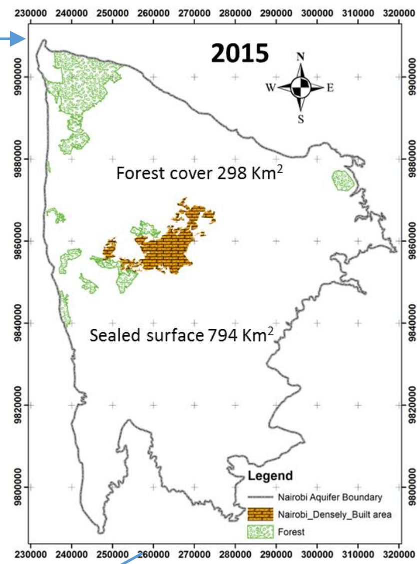
- Observed declining GW levels in monitoring wells

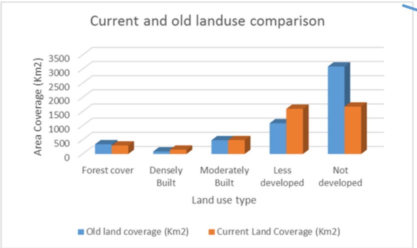


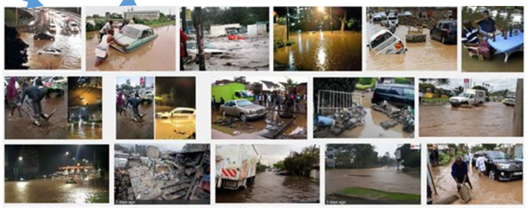


Human Impact on the land cover



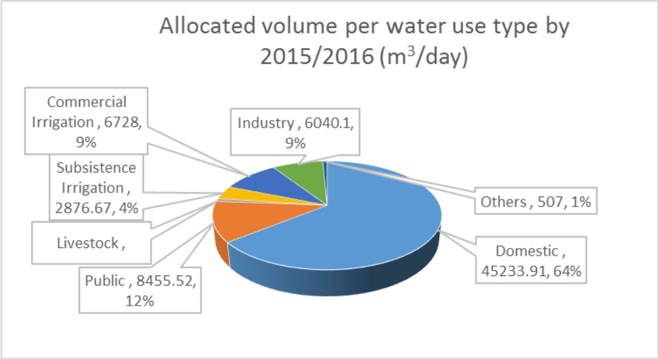




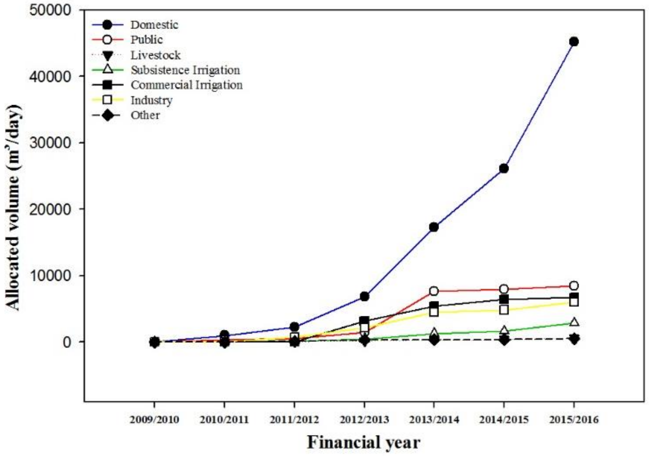


Impact on groundwater recharge?

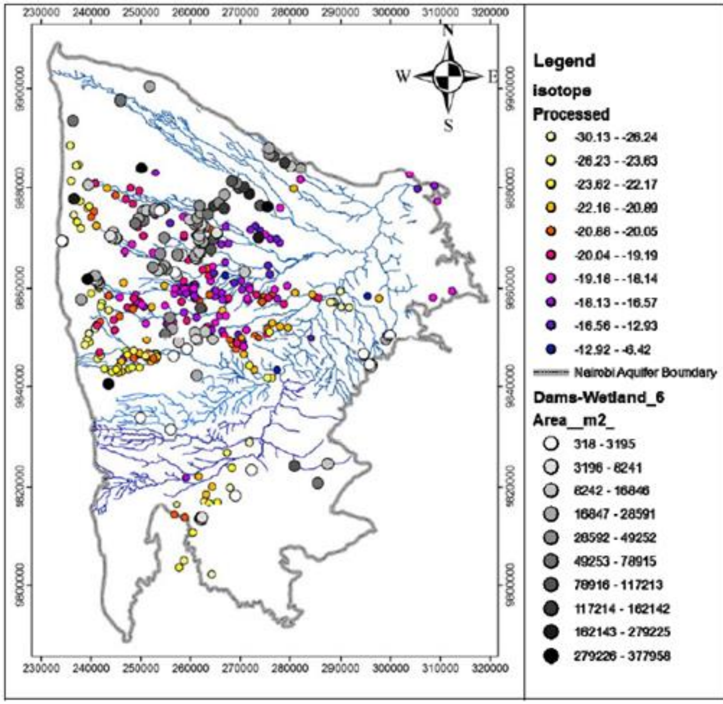
Groundwater Abstraction trend of the Area

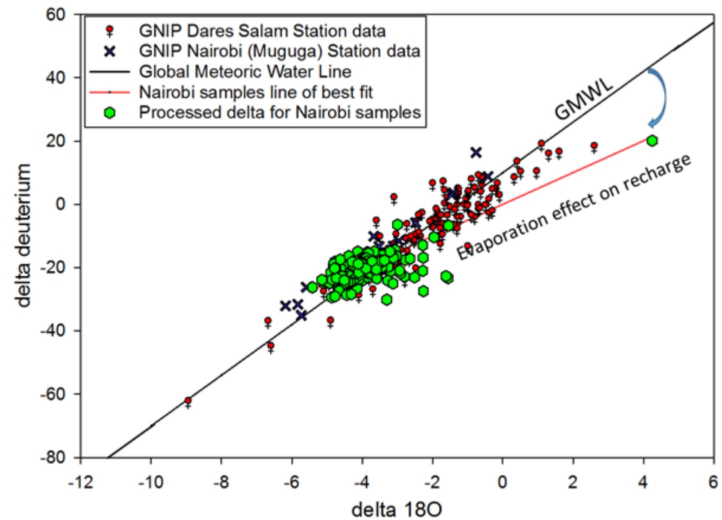


Nairobi groundwater allocated cumulative volume in 7 Financial years



Stable Isotope δ^2H and $\delta^{18}O$ (Preliminary Results)

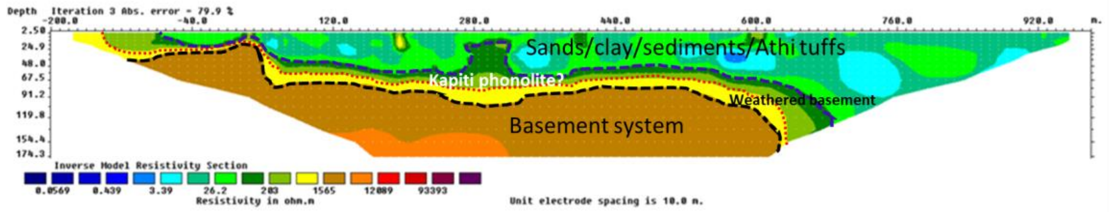




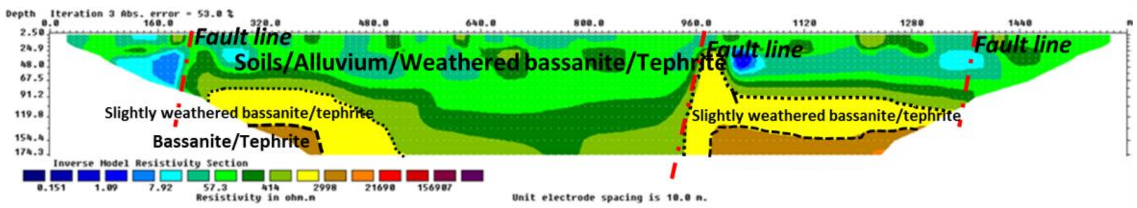
Nairobi aquifer system stable isotope graded results in relation to reservoirs and wetlands

- NAS GNIP typical tropical rain observation
- NAS water cooler compared to Dares Salam
- Effect of evaporation on recharge
- Heavier isotope gets depleted towards mainland
- Orographic effects making Nairobi Isotopes lighter

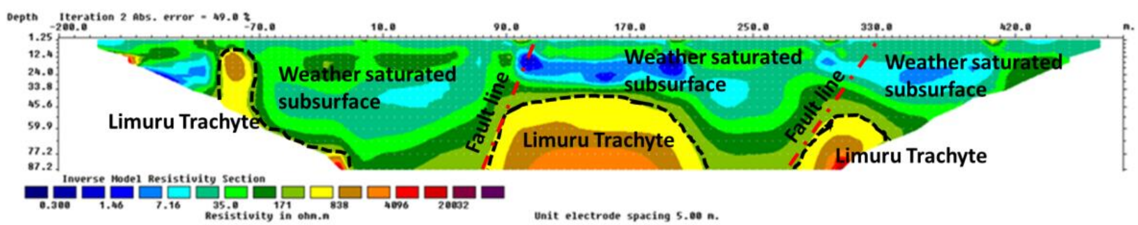
Electrical Resistivity Tomography Investigation (Preliminary Results)



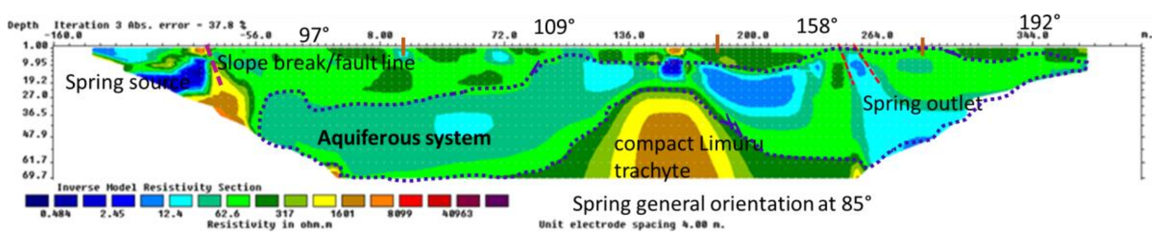
Basement profile



Rift profile

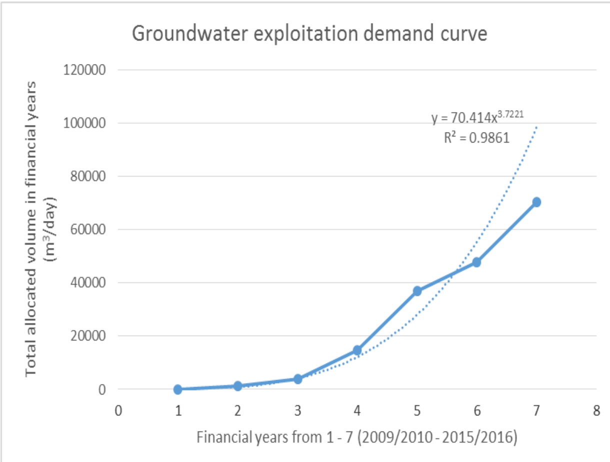


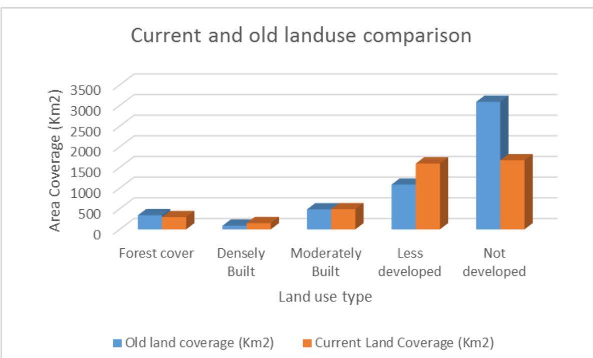
Swamp/wetland profile



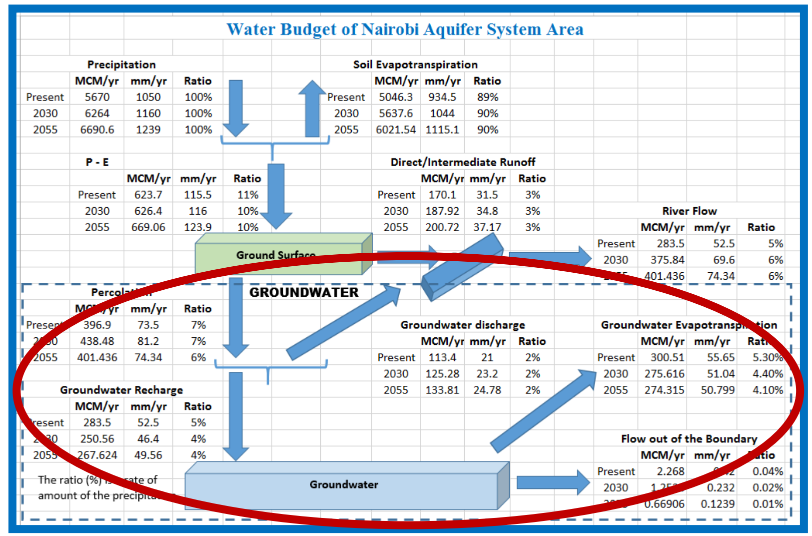
Spring profile

Modelling Human impact and Climate Change on the Area





Water budget model adopted from JICA team National Water Master plan (Kenya 2012).



Development of a 3D physically based hydrogeological model

Initial findings

- Exponential increase of groundwater abstraction in the last decade
- Declining groundwater table by tens of meters within Nairobi
- Possible surface water (springs/wetlands)/ groundwater interaction (ERT investigations)
- Consistent gentle slope geometry of basement metamorphic overlain by the deposits of lava flows and sediments (aquifer base) (ERT).
- Higher density faults form GW recharge pathways
- Orographic effect and infiltration from reservoirs influences the isotopic nature (δ^2H & $\delta^{18}O$) of NAS GW

Conclusions

- Nairobi **temperature and rainfall is expected to increase** in next decades (0.0102°C & 0.425 mm/annum) hence flooding and focussed recharge, flood health related hazards
- **Continuous drop of groundwater level is expected** with increasing demand which could lead depletion of the aquifer if sustainability steps are not taken into consideration.
- Continuous improper infrastructure development has increased run-off, while modifying spatiotemporal groundwater recharge patterns
- Quantification of **natural recharge** and managed aquifer recharge recommended to ensure sustainable groundwater exploitation.

Ongoing and future work

- Geophysics – data inversion with topography (***Ongoing***)
- Further analysis of isotope data – spatial recharge processes and GW/SW interaction (***Ongoing***)
- Data integration and groundwater numerical model set up (***Oct 2016 - …***)
- Tiwi-Mombasa coastal case (***2017 - …***)

ACKNOWLEDGEMENT

WATER RESOURCES MANAGEMENT AUTHORITY

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