Advanced Survey of Groundwater Resources of Northern and Central Turkana County, Kenya

Conducted by:

RADAR TECHNOLOGIES INTERNATIONAL

Implemented by:

United Nations Educational, Scientific and Cultural Organization

Framework:

Groundwater Resources Investigation for Drought Mitigation in Africa Programme

Client:

Republic of Kenya
Ministry of Environment, Water and Natural Resources

Contribution to the national development strategy:

KENYA VISION 2030
TOWARDS A GLOBALLY COMPETITIVE AND PROSPEROUS NATION

Financed by:

JAPAN
Official Development Assistance

OVERVIEW

Target area	Northern and central Turkana County
Beneficiary	Ministry of Environment, Water and Natural Resources
Client	UNESCO
Budget	$700,000 ($150,000 for exploratory drilling)
Donor	Japan (Official Development Assistance)
Duration	July 2012 – June 2013
Contractor	Radar Technologies International (RTI)
National framework	Kenya Vision 2030
Regional frameworks	GRIDMAP, IGAD
Parent Project	Strengthening capacity to combat drought and famine in the Horn of Africa (Ethiopia, Kenya, Somalia), $1.5 million
Scientific review	Technical Scientific Committee (Kenya)

OBJECTIVES

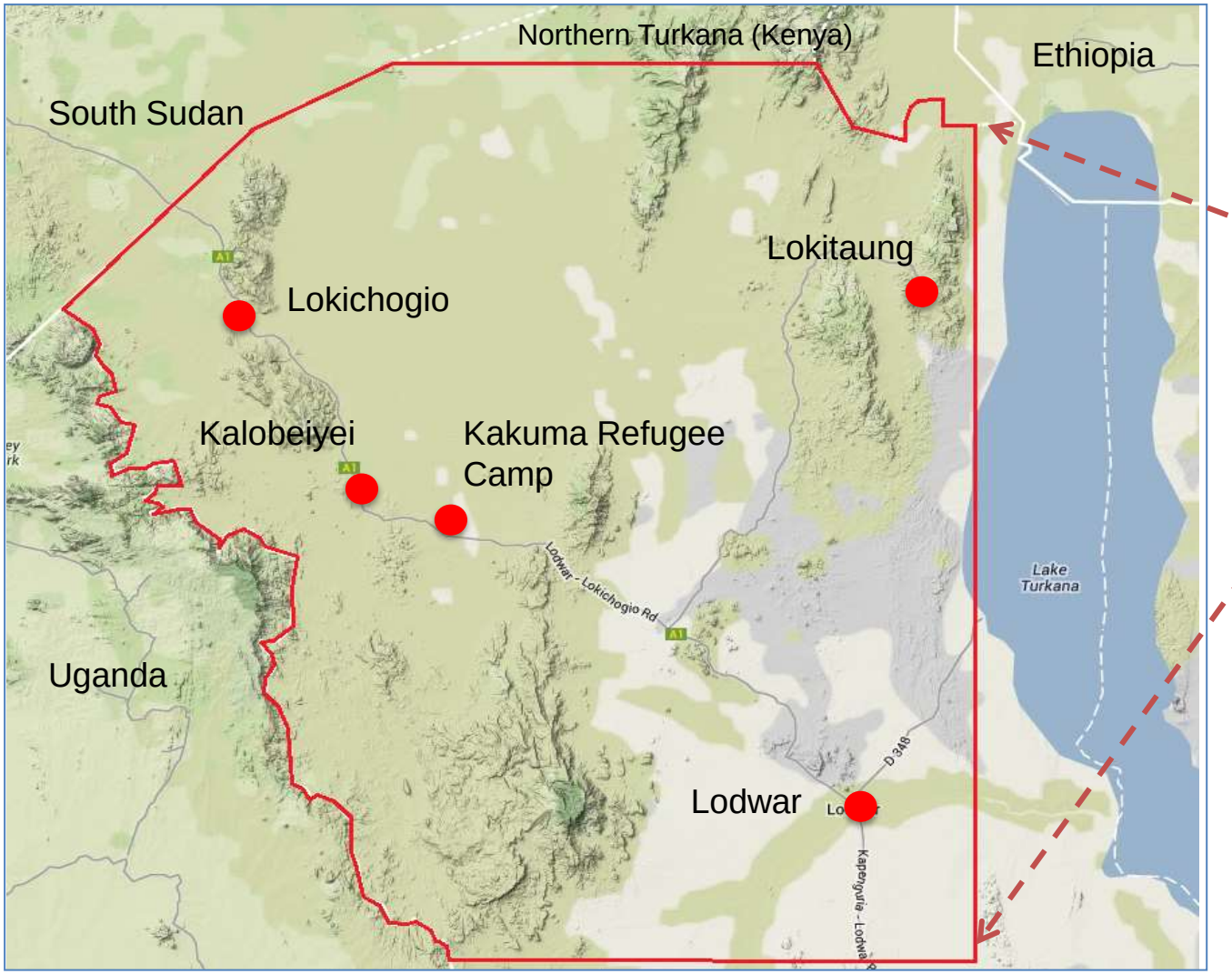
(1) To survey and assess the hydrogeology of northern and central Turkana County

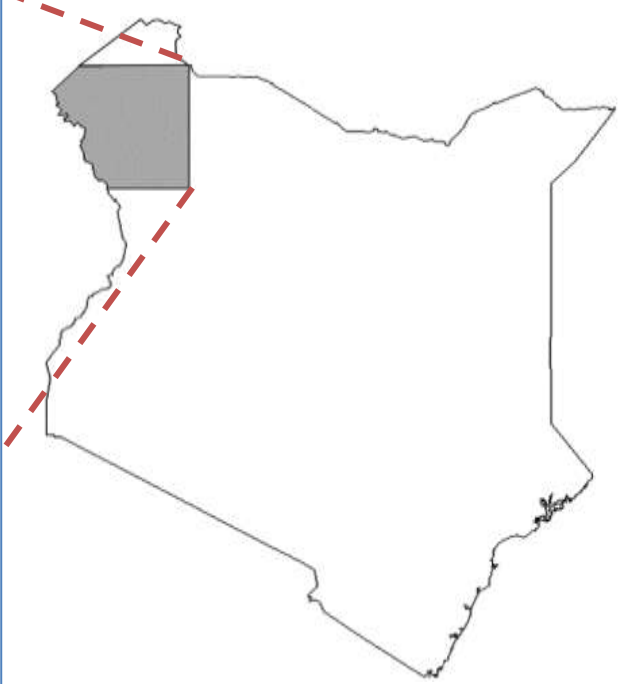
(1) To identify and assess a maximum quantity of new clean groundwater resources for populations in the survey area, with particular focus on the communities of Lodwar, Lokichogio and Kakuma and Kalobeiyei

(1) To assess the potential of groundwater for development, with a focus on both shallow and deep structures

SURVEY AREA

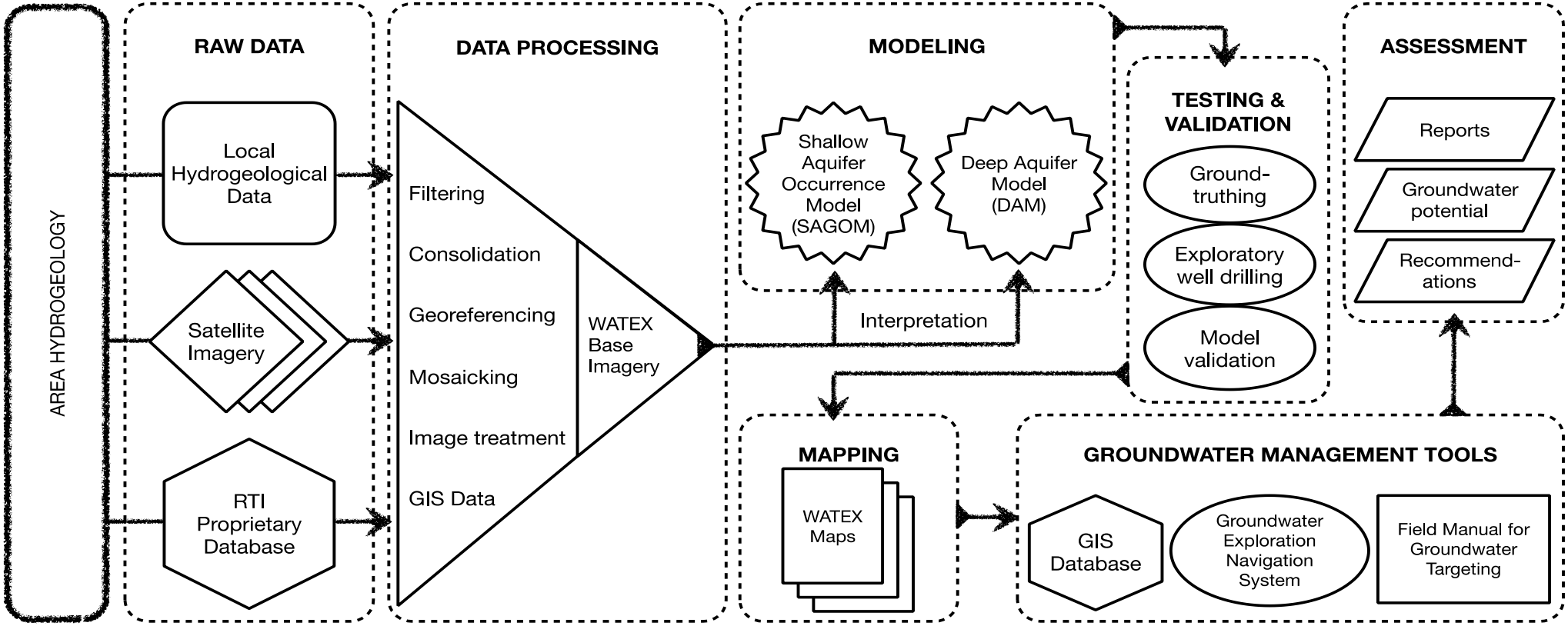
Northern and Central Turkana County, (36,000 km^2)



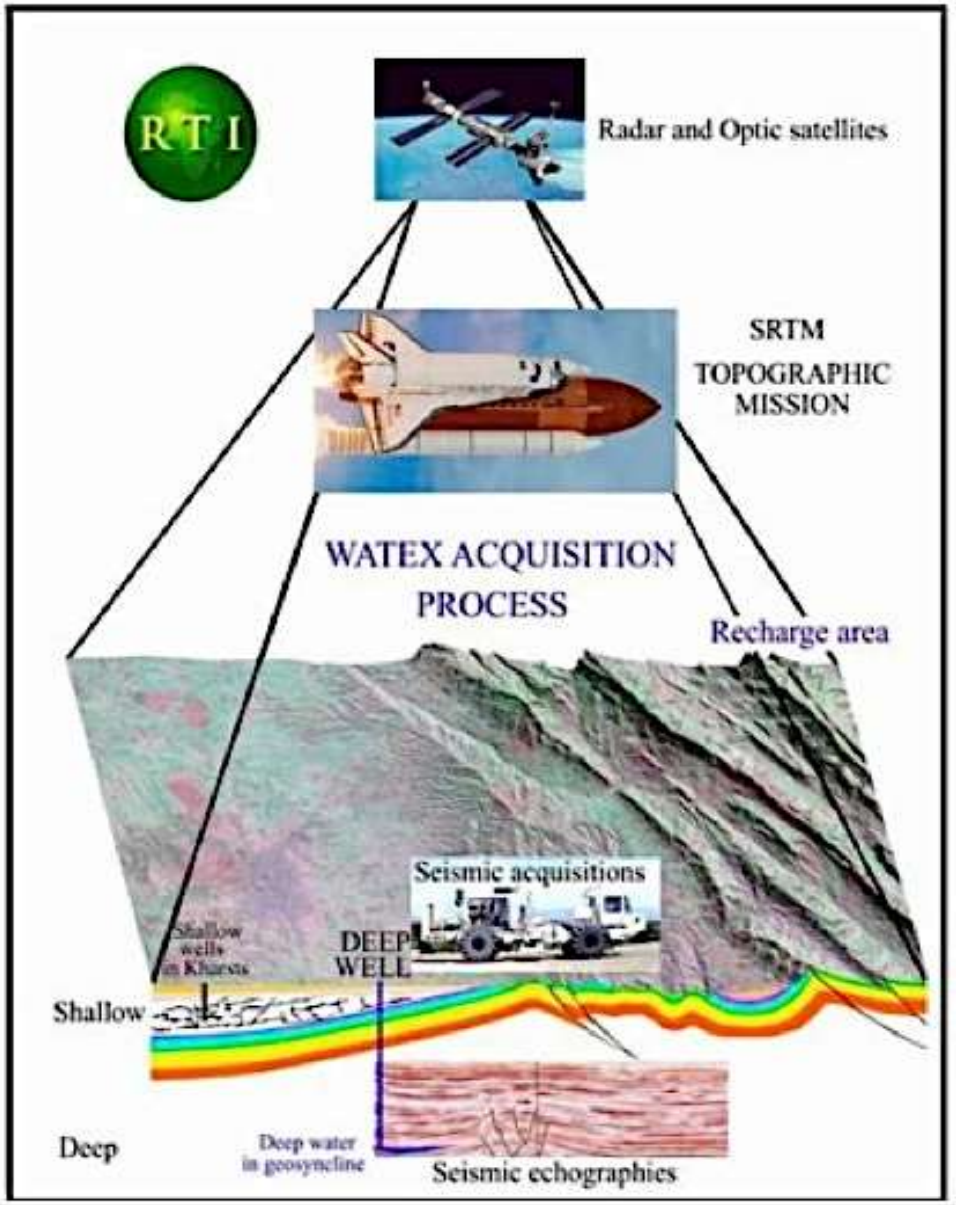


METHODOLOGY

Water for everyone, everywhere
watex



METHODOLOGY



Remote-sensing layers

Radar and optical satellite imagery


Radar


Landsat


SRTM

Traditional Hydrogeological Layers

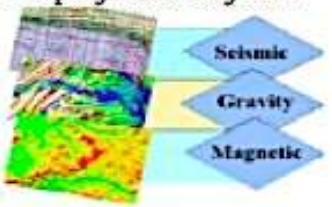

Geology


Hydro Maps


Rainfalls


Rivers and
Watershed

Geophysical layers



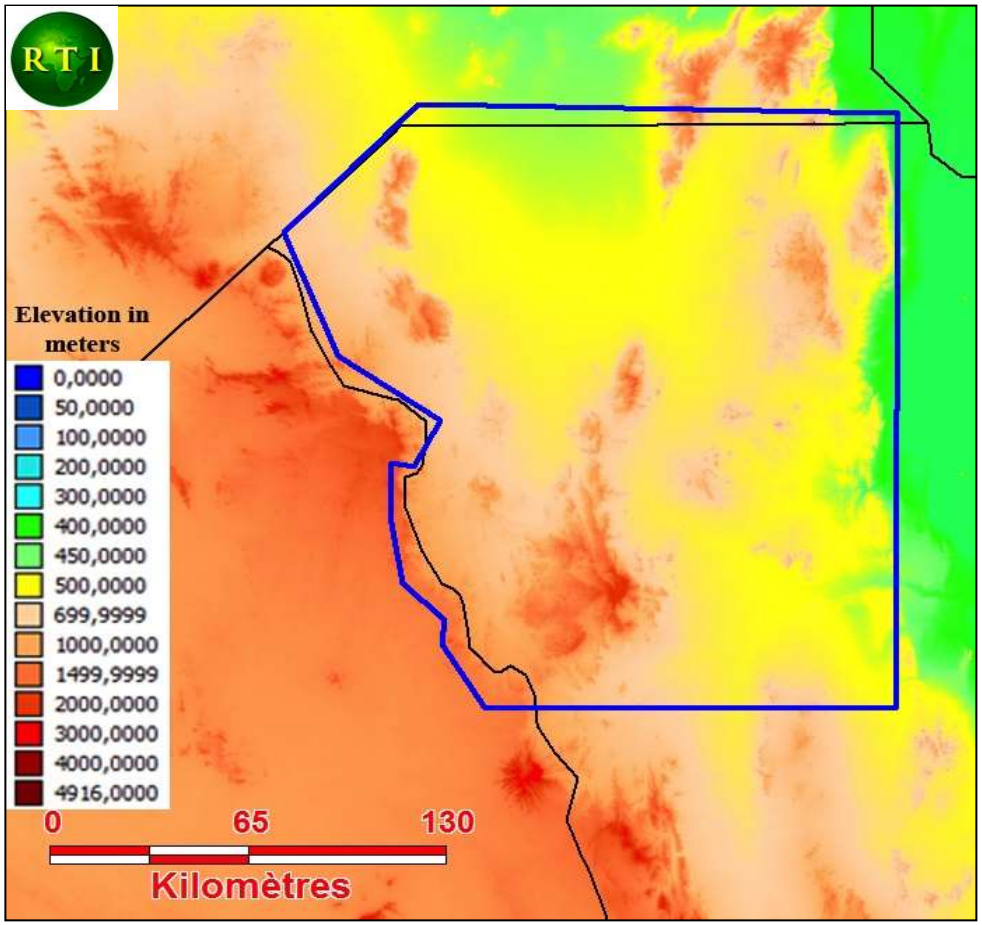
METHODOLOGY

WATEX Landsat 7 Processing: Lithological contrasting

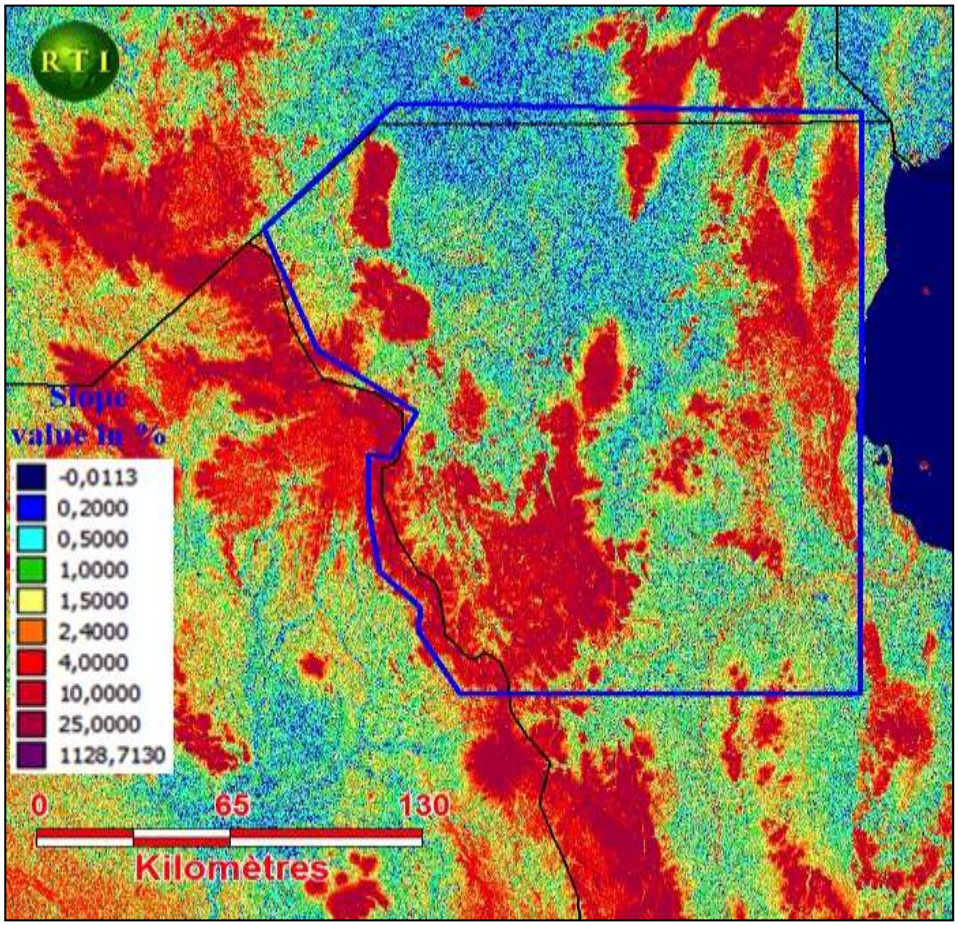
METHODOLOGY

WATEX SRTM Processing: Elevation and slope evaluation

Elevations



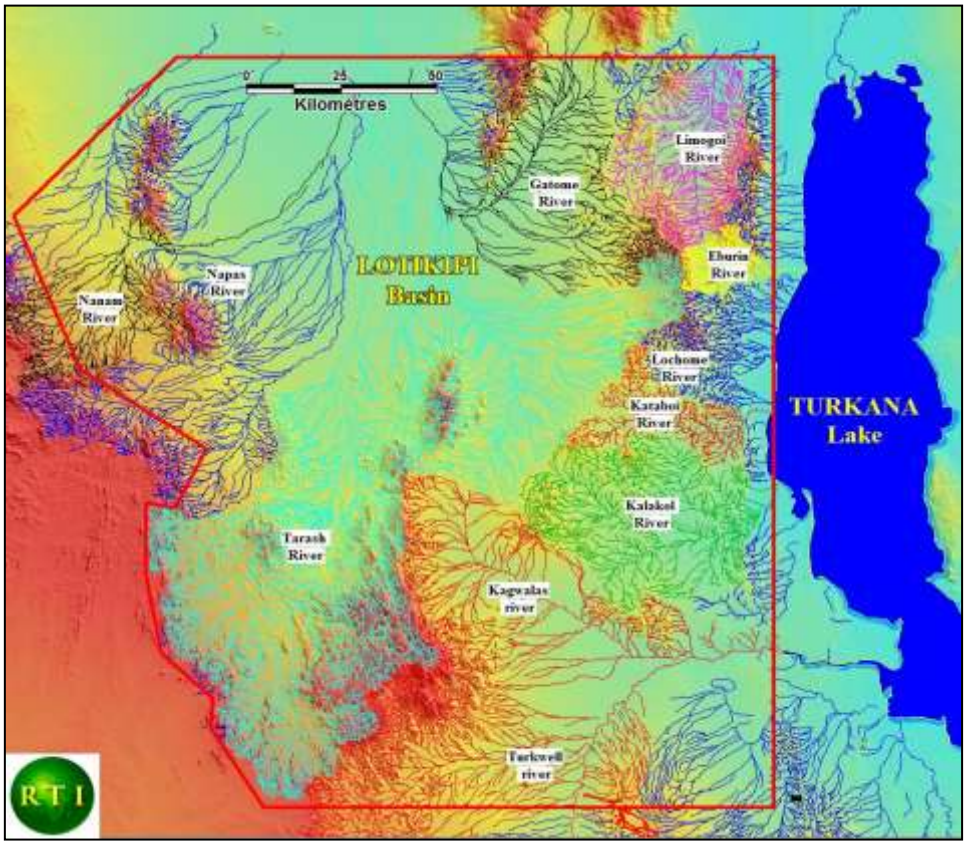
Slopes



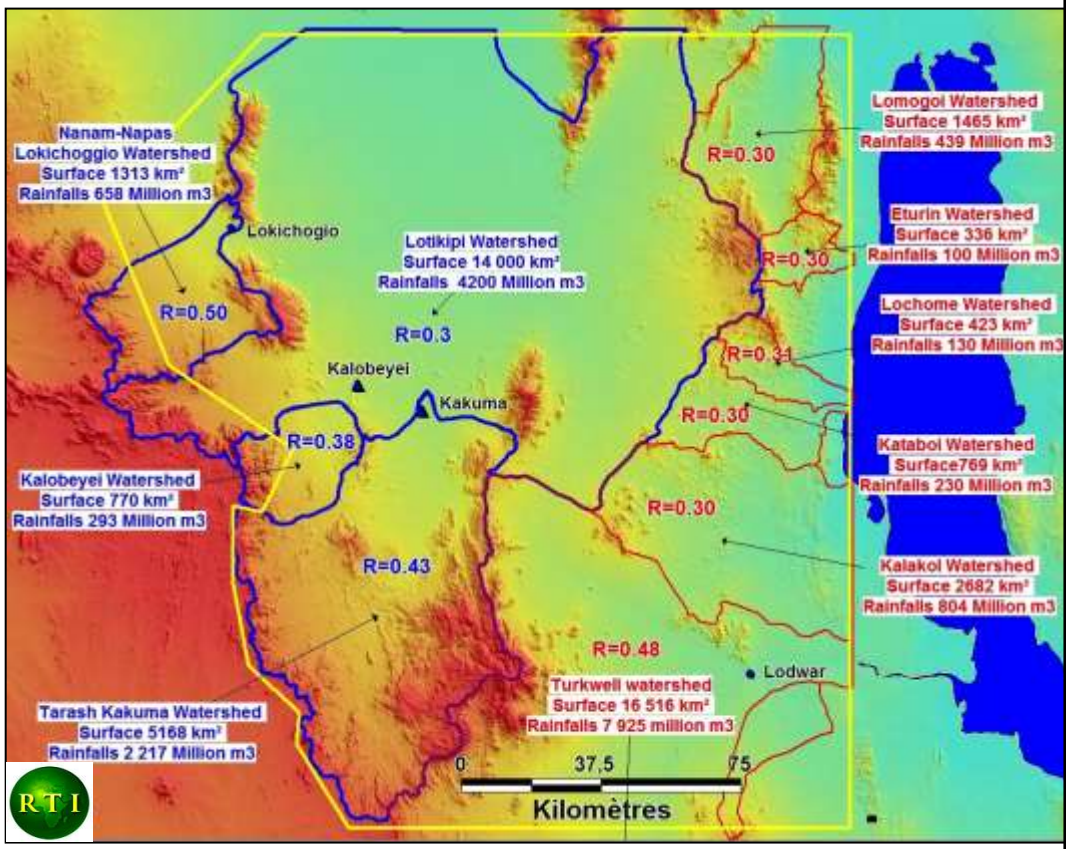
METHODOLOGY

Watershed Dynamics Evaluation

Surface Drainage



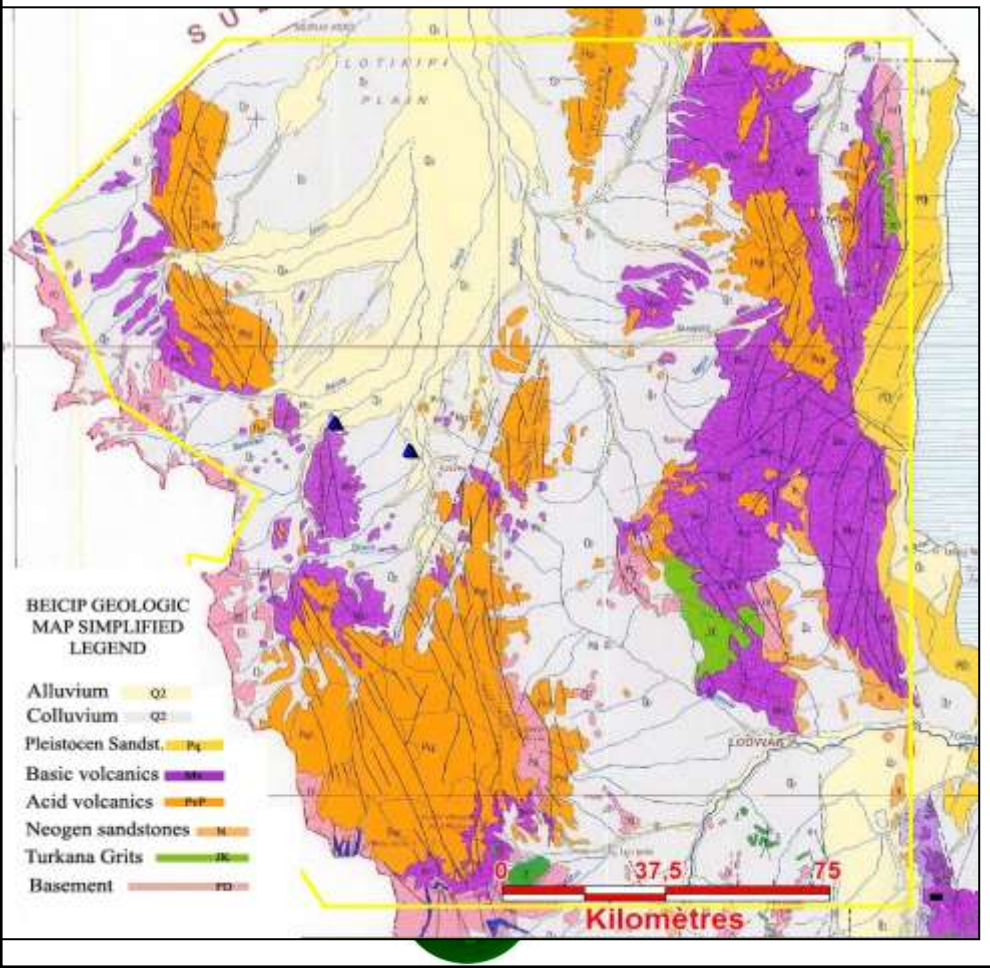
Catchment boundaries and harvesting



METHODOLOGY

Geological assessment

Geological Map, 1987

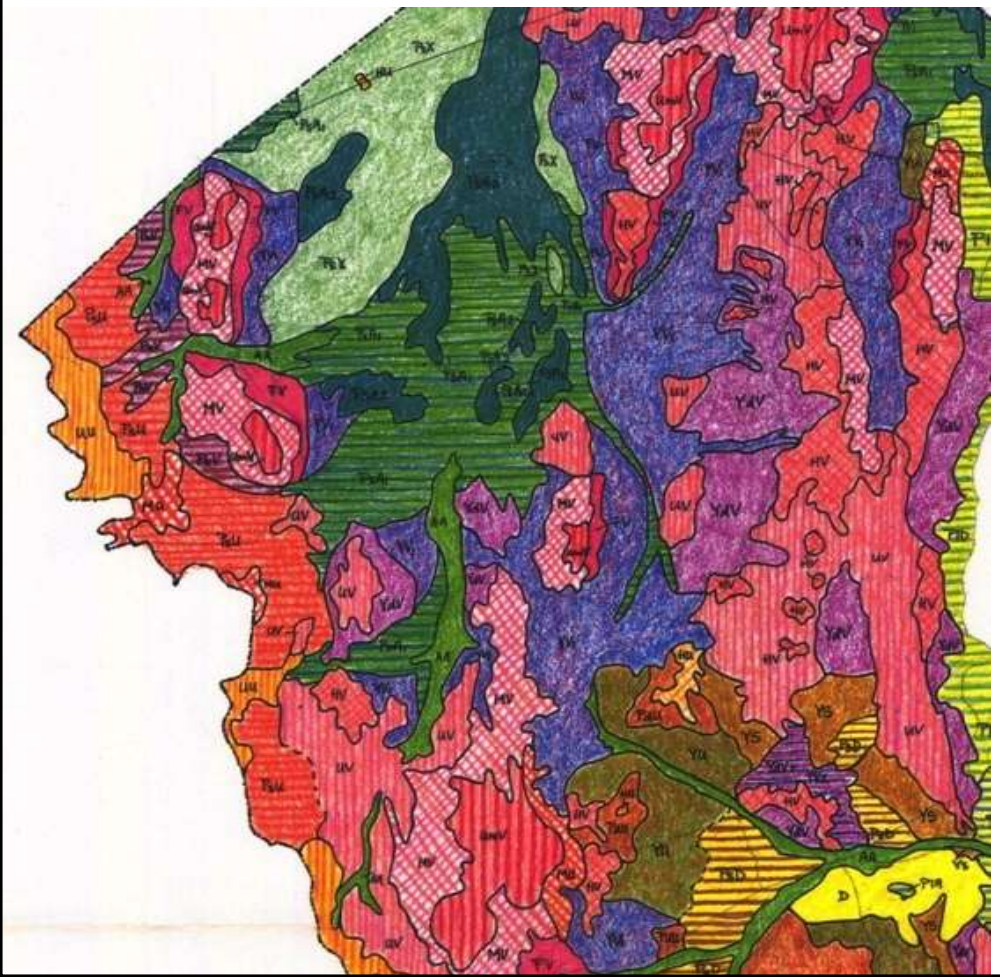


Field survey, RTI, 2012

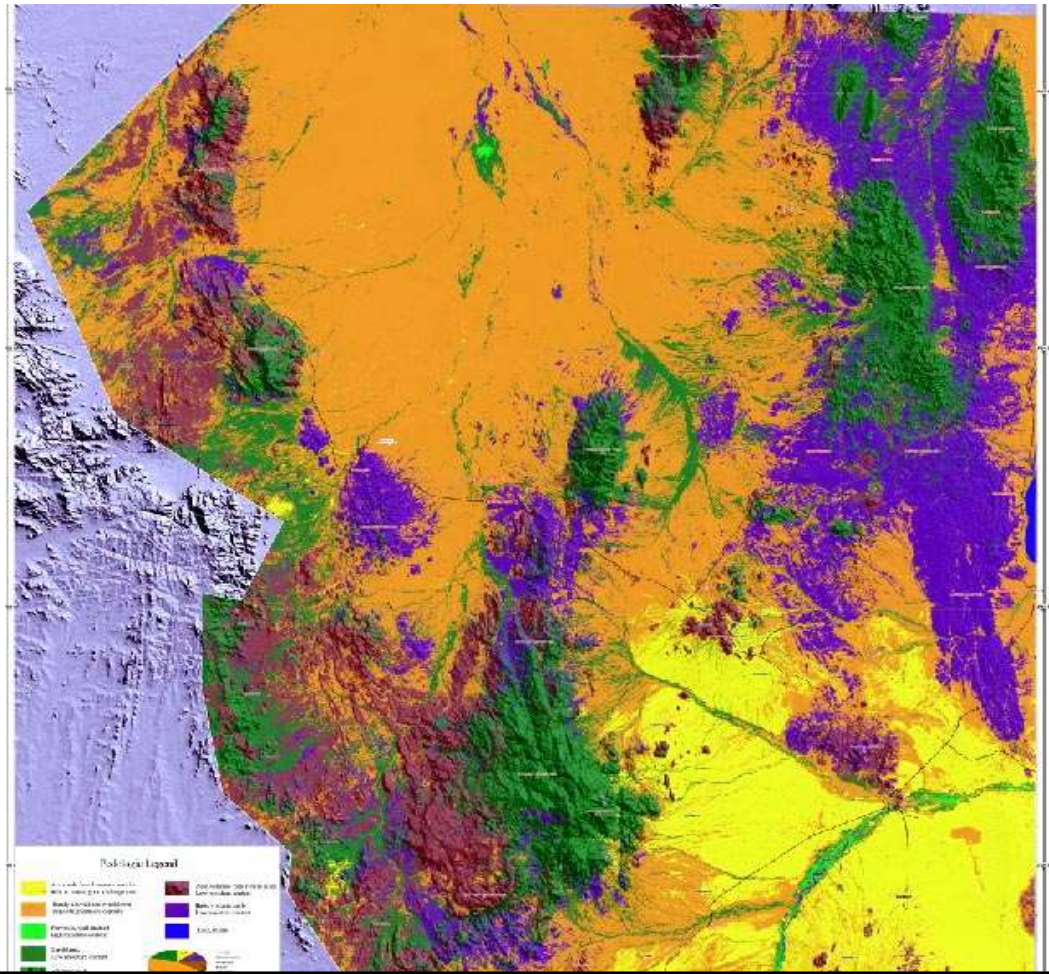
METHODOLOGY

Soil Type Classification

Old soil map, 1987

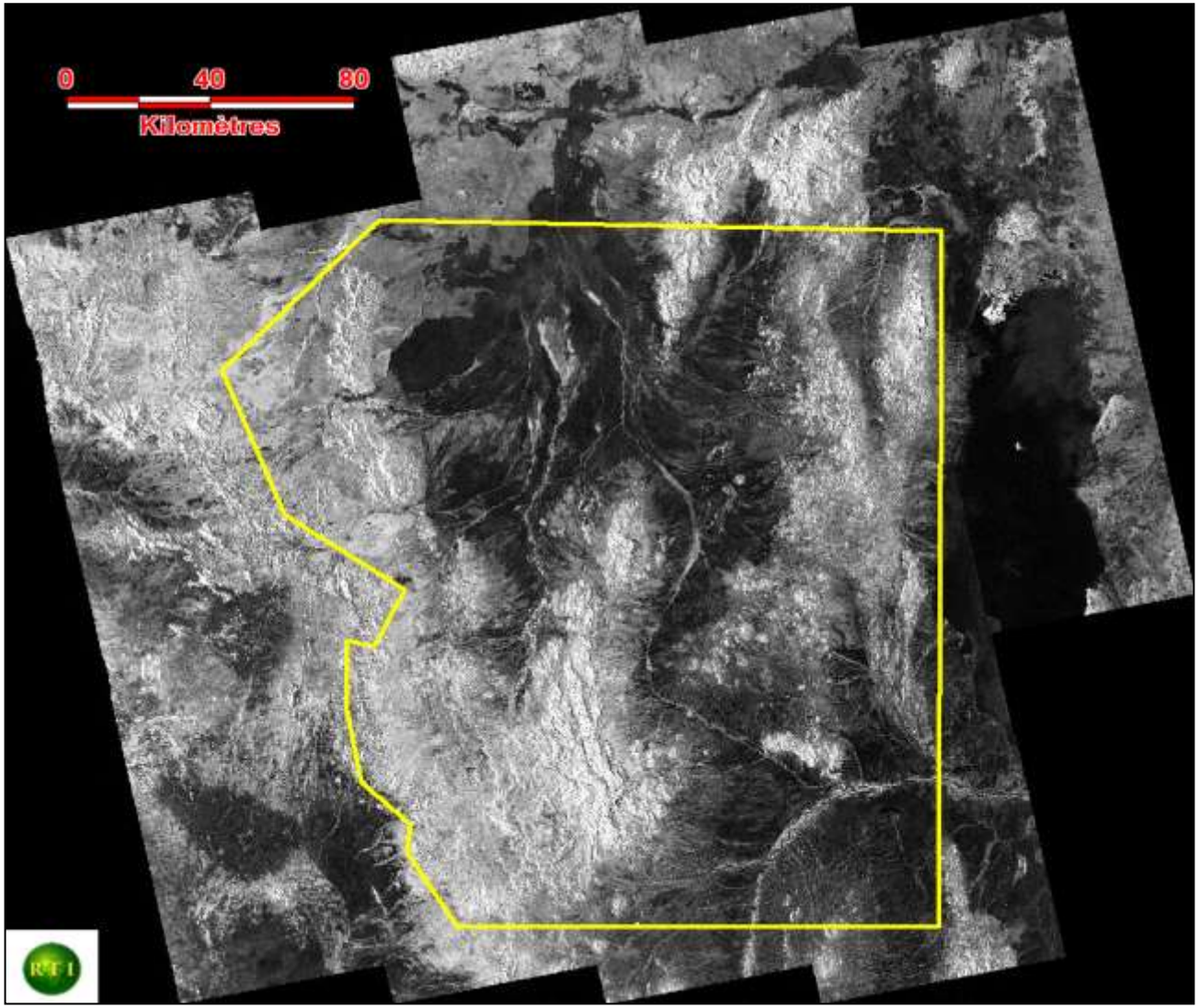


New soil classification map, RTI, 2013



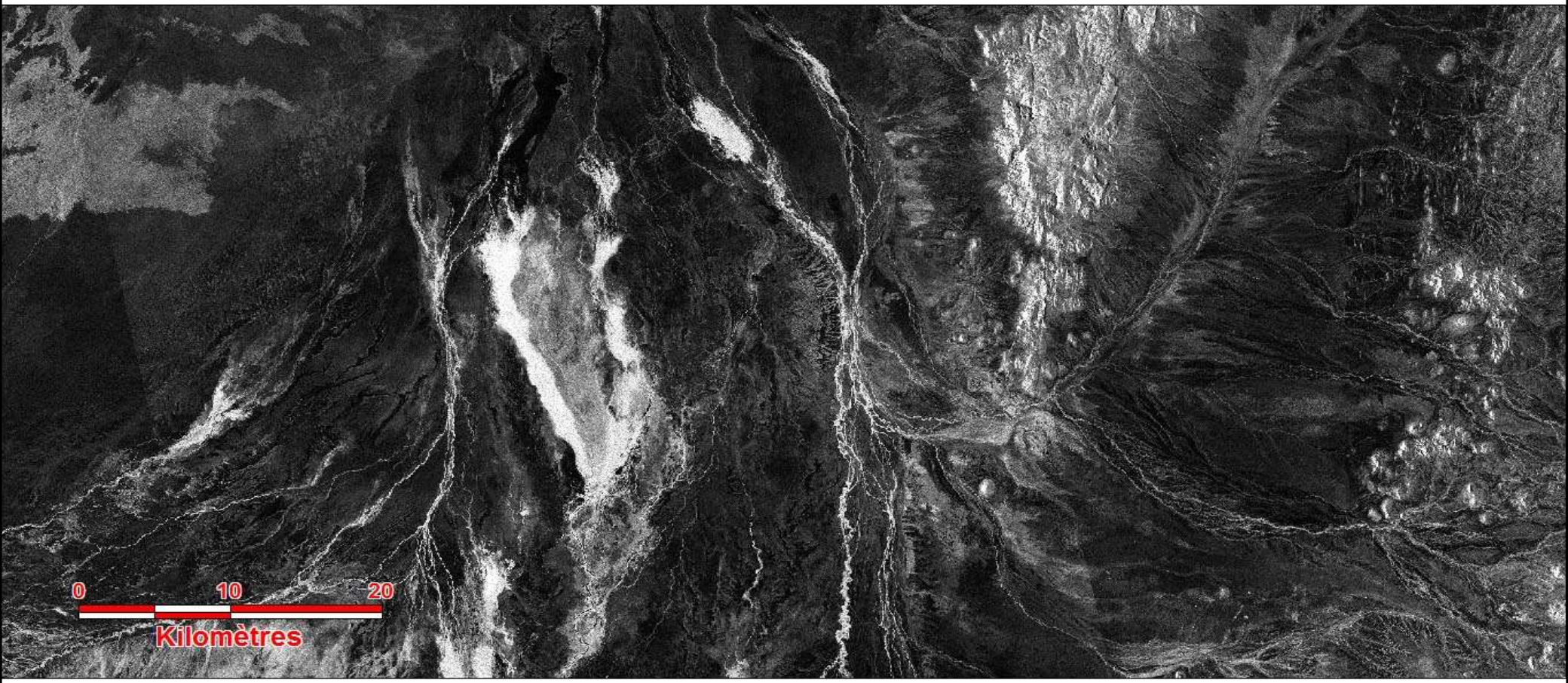
METHODOLOGY

Raw Spatial Aperture Radar Imagery: Unprocessed, showing surface only



METHODOLOGY

WATEX Radar Processing: Detecting and classifying shallow groundwater (0-80 m)



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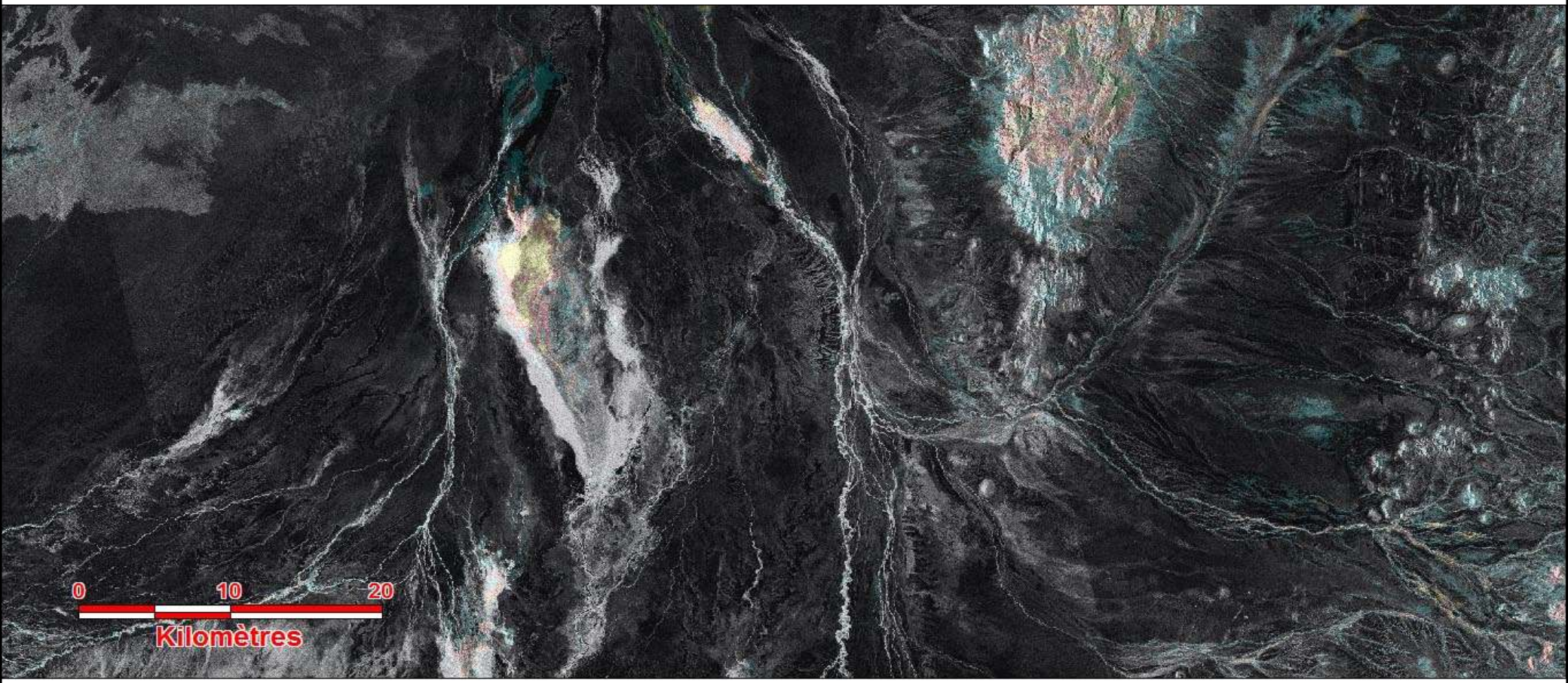

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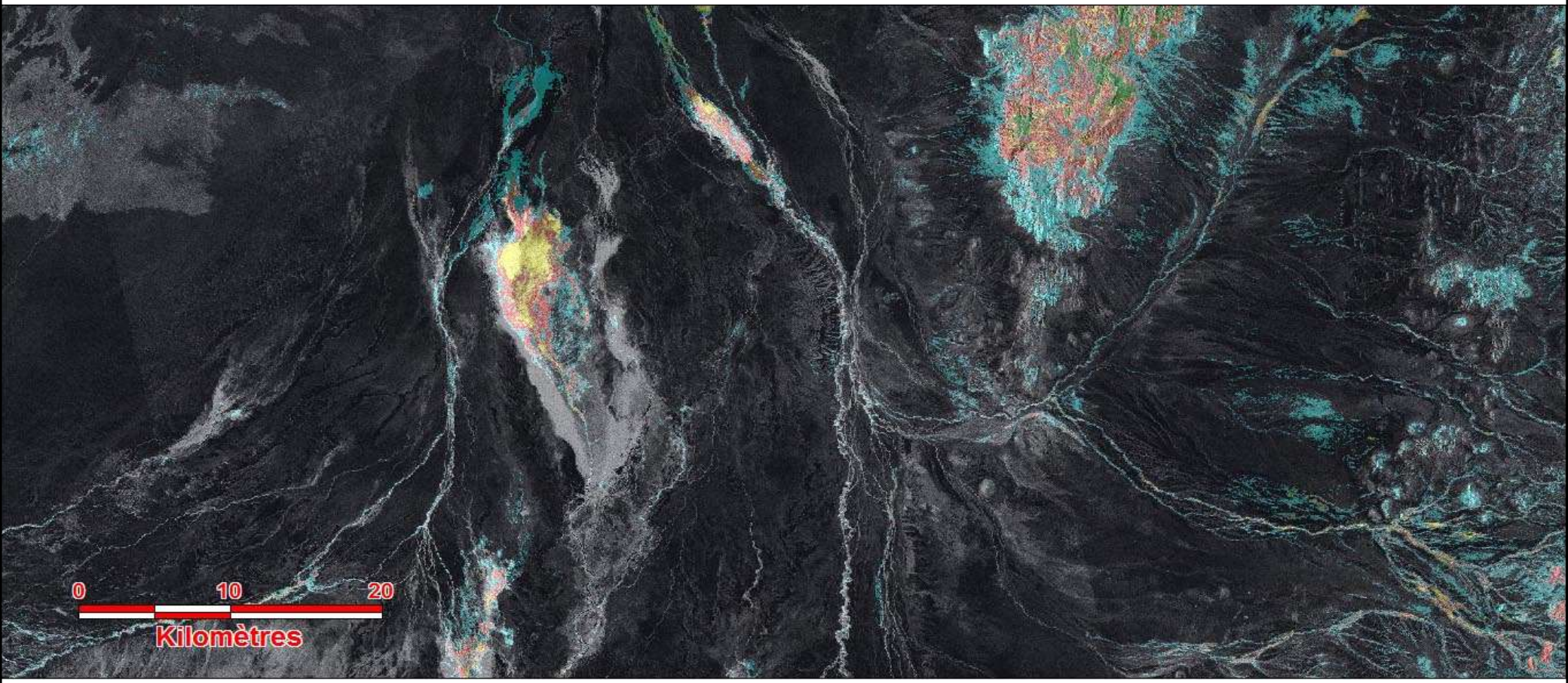

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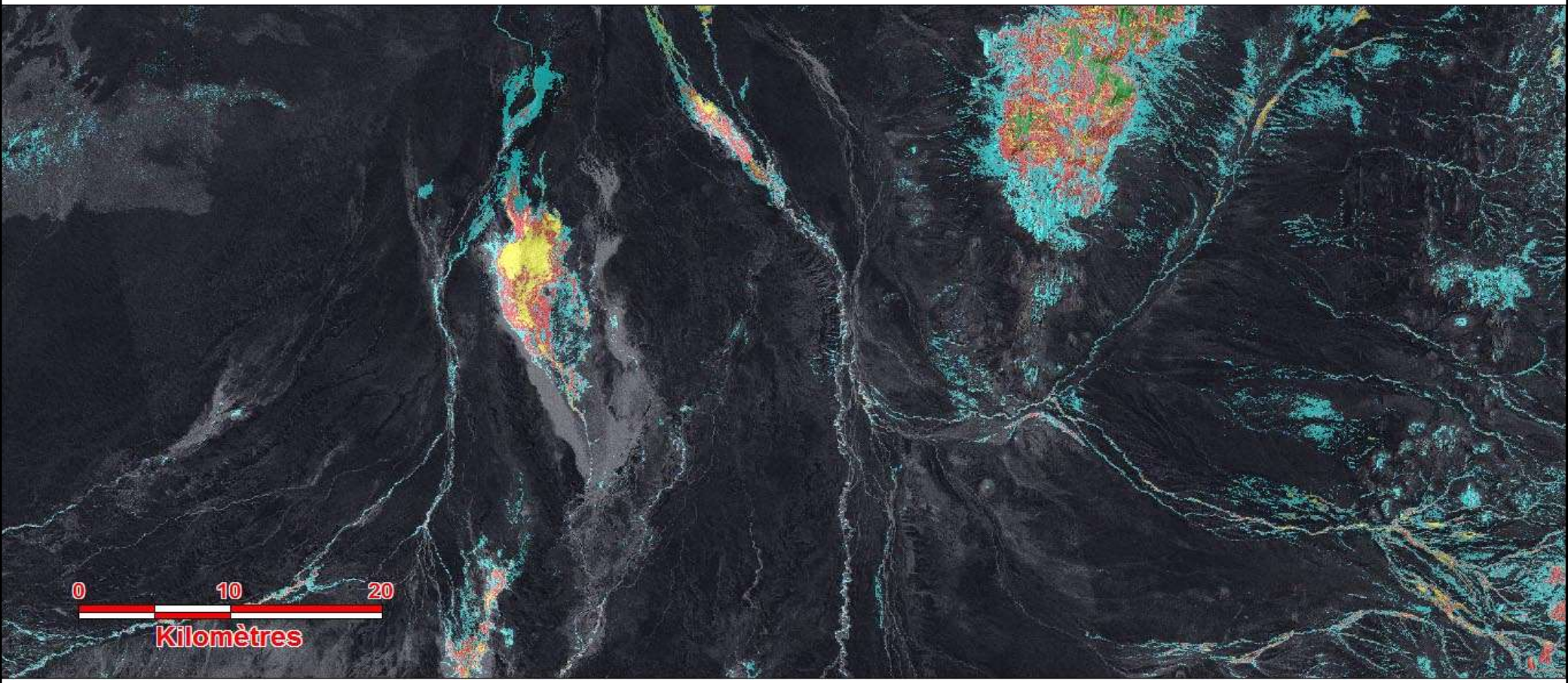

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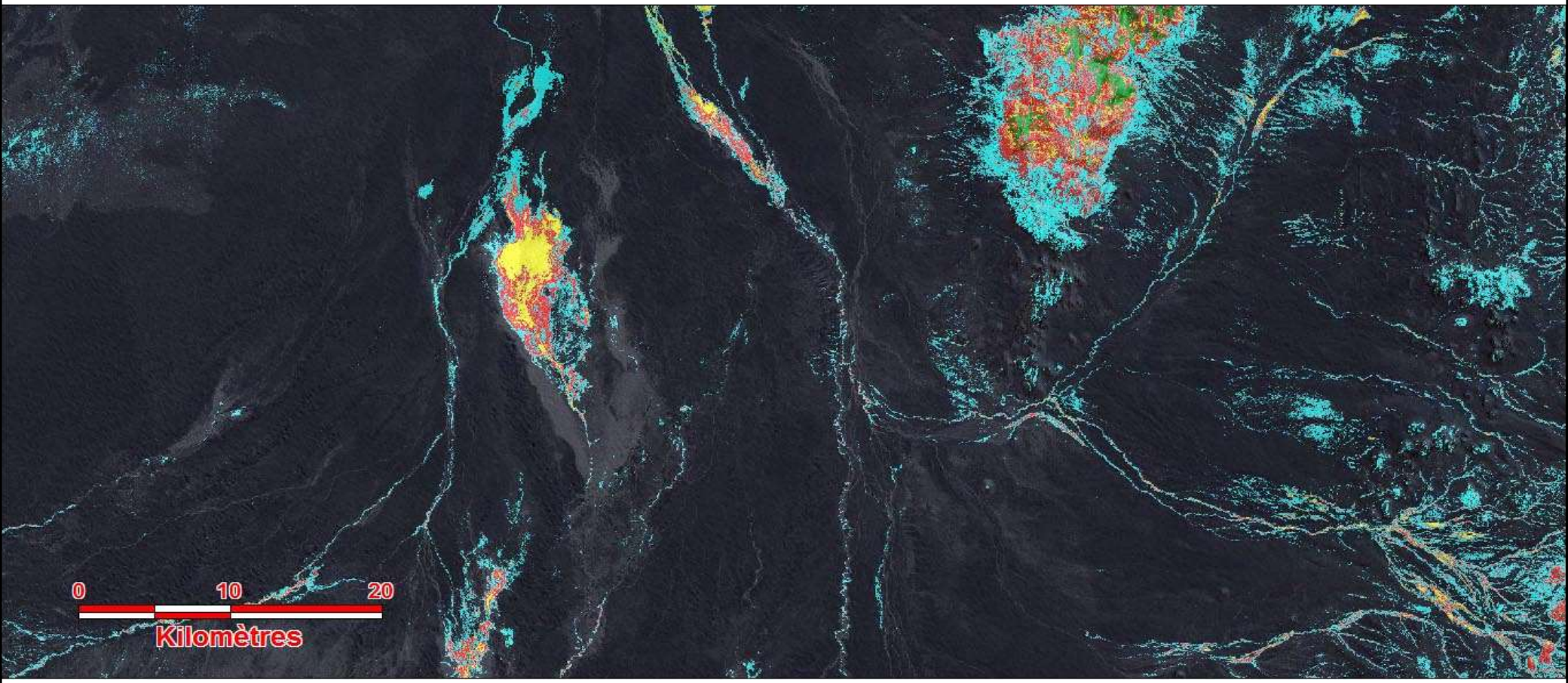

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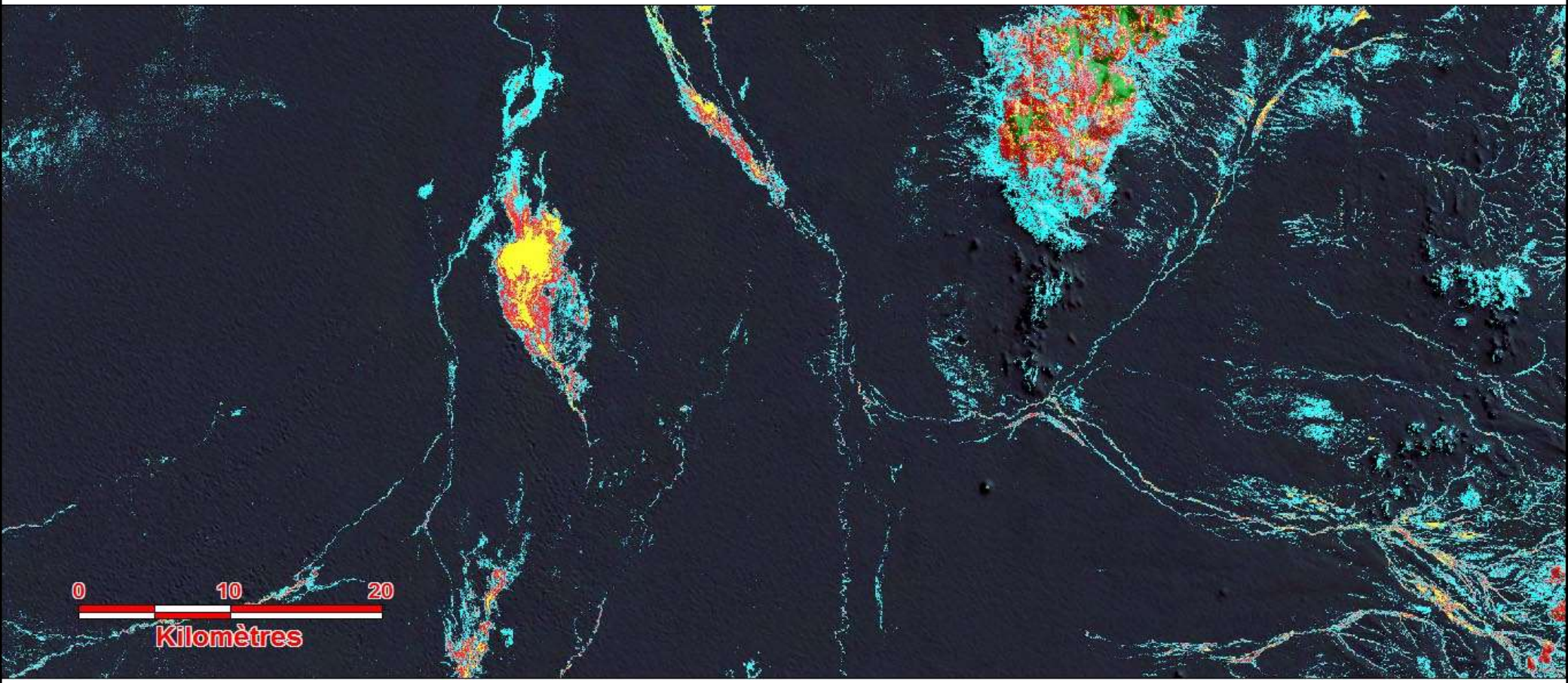


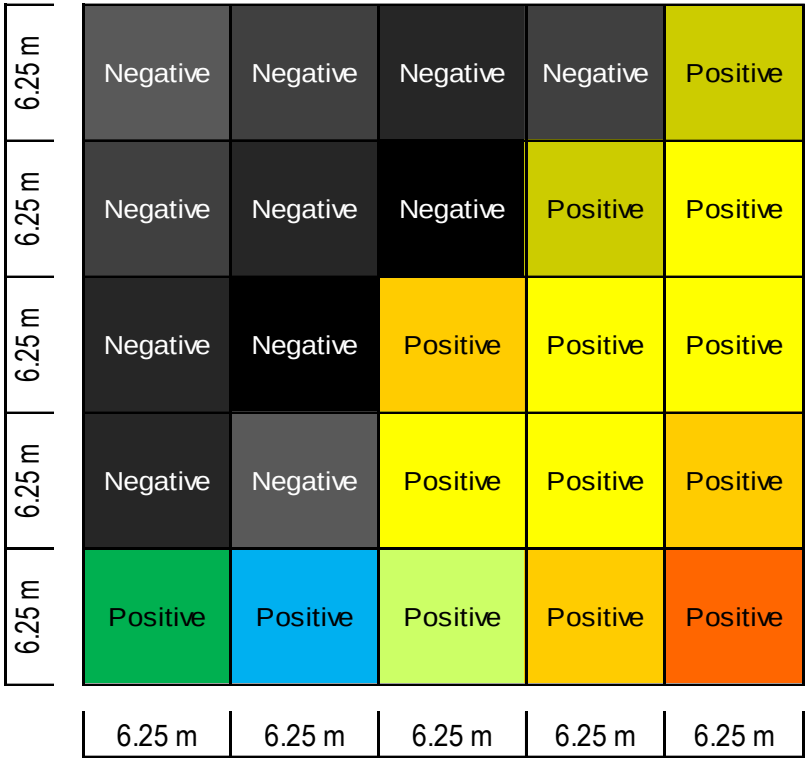
METHODOLOGY

WATEX Shallow Aquifer Occurrence Model (SAGOM): Classifying shallow groundwater (0-80 m)

Groundwater potential color coding

Pixel Color	Occurrence potential at location
Yellow	Minimum of 90%. These pixels represent fracture discharges in alluvial sediments, or pure alluvial aquifers.
Red	75% probability of aquifer presence if combined with a conductive fracture.
Light blue	30% probability of aquifer presence if combined with a conductive fracture.
Green	25% probability of groundwater occurrence, located over hills and mountains. Wells in these pixels should only be drilled with the presence of a conductive fracture
Black / dark	0-5%, minimal occurrence potential, likely to be dry or have little potential for groundwater occurrence.

Pixel resolution (39 m2)



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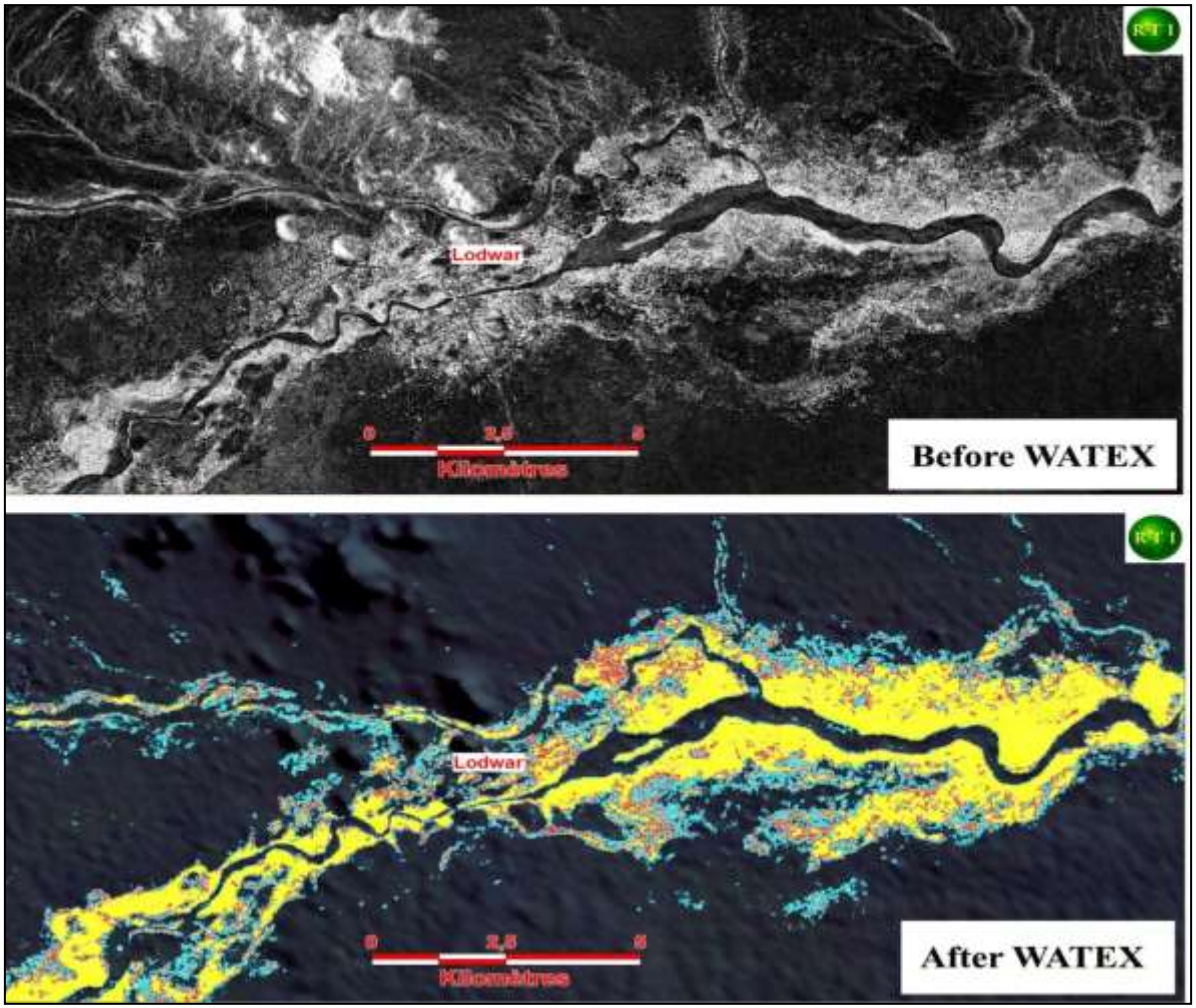
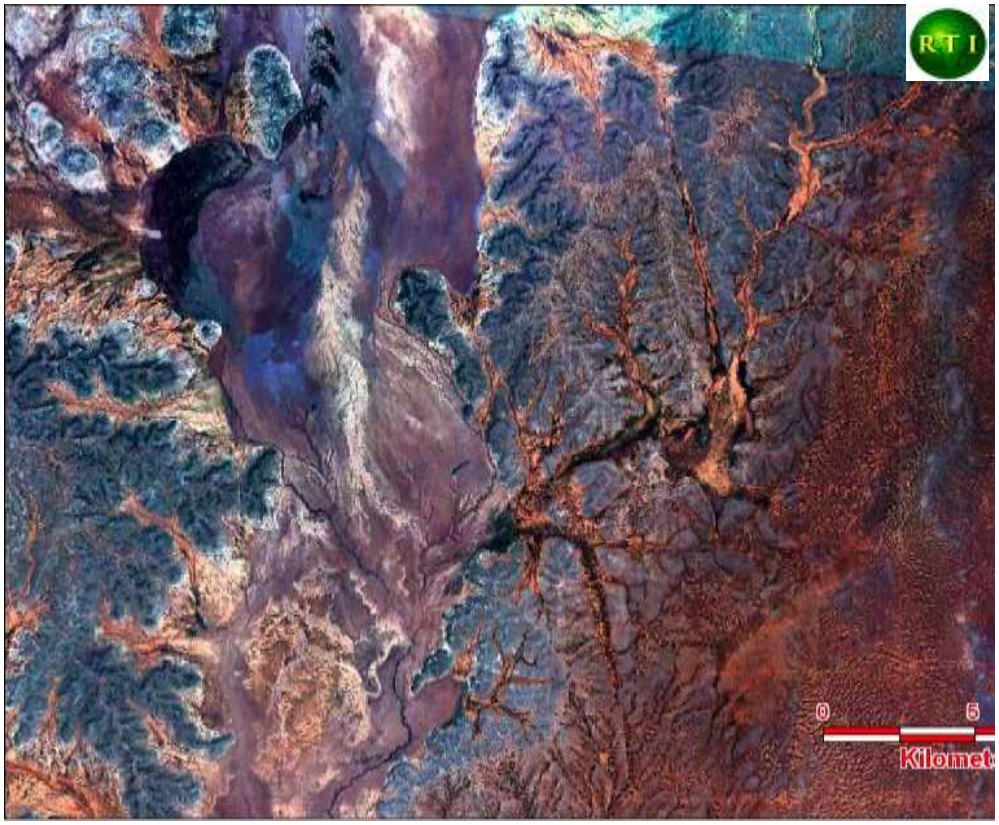


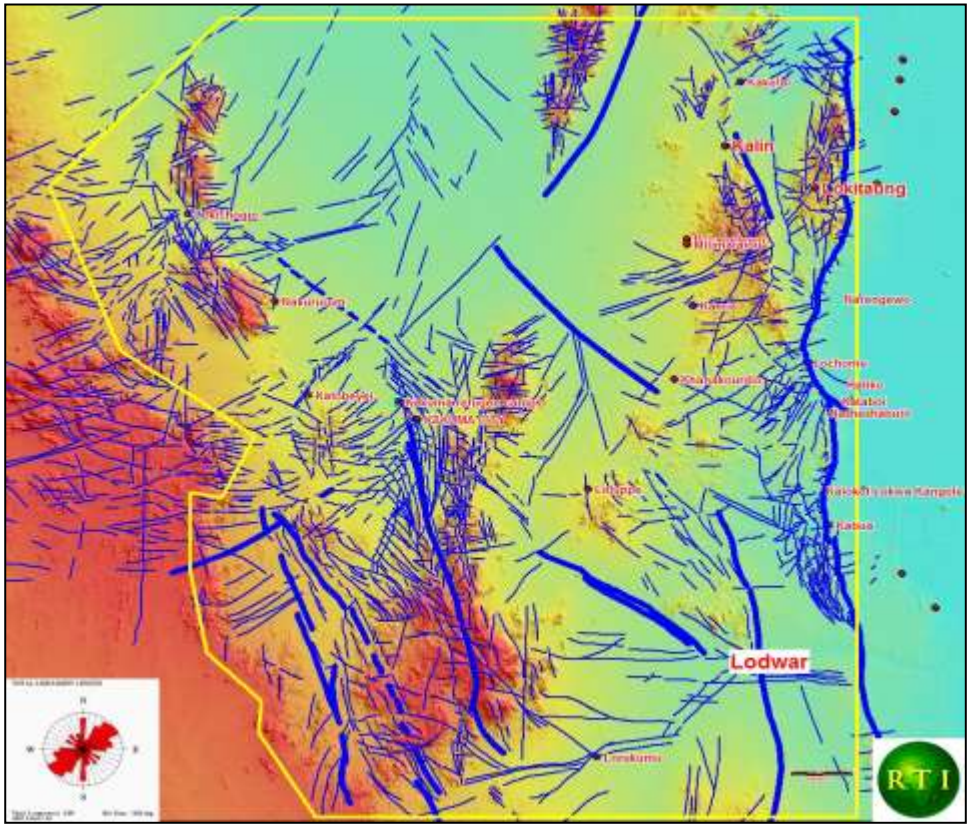
METHODOLOGY

WATEX fracture mapping and classification

WATEX Landsat and SRTM processing for fractures, RTI, 2008



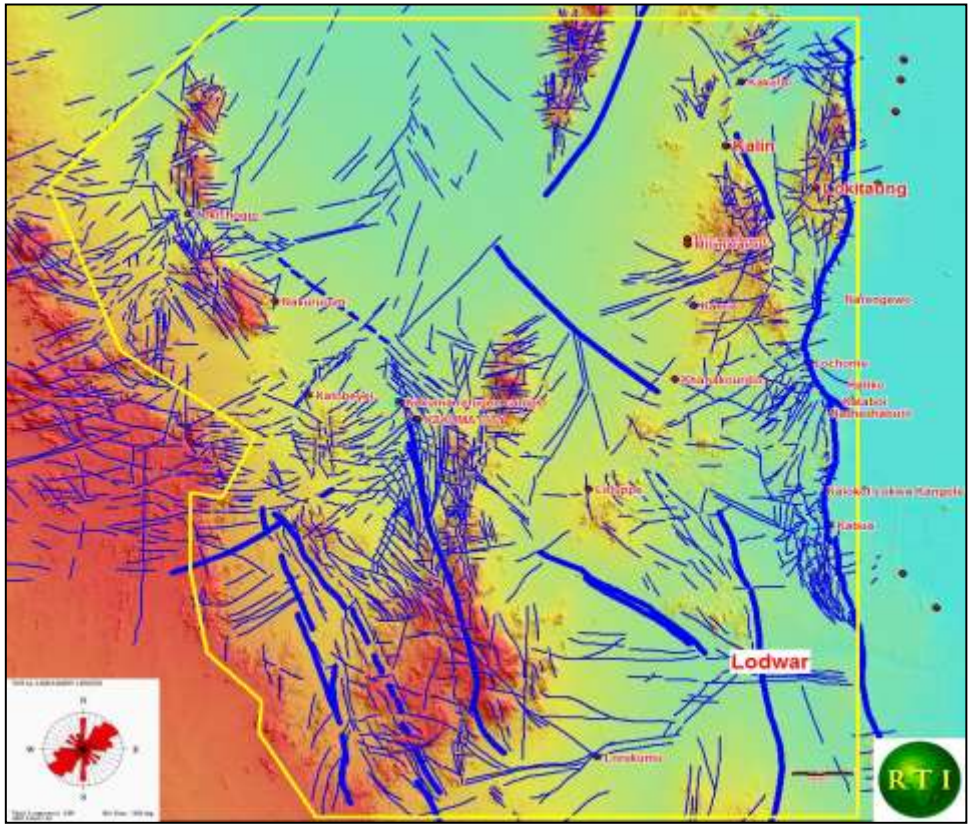
Regional fracture map, RTI, 2013



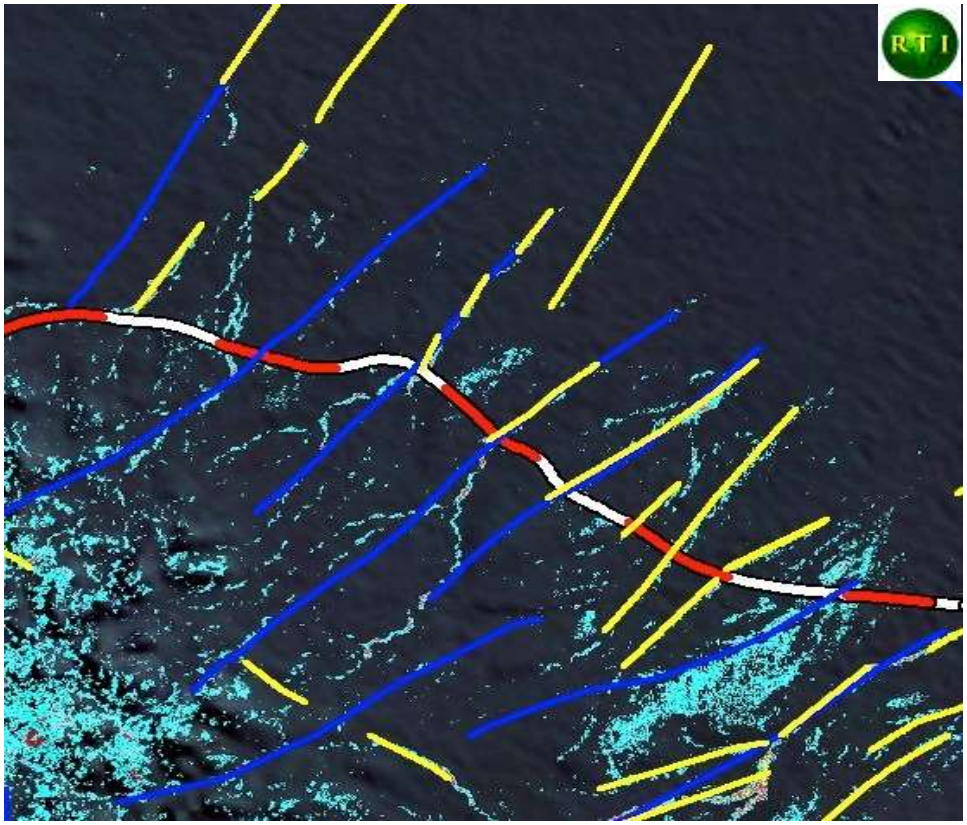
METHODOLOGY

WATEX fracture mapping and classification

Regional fracture map, RTI, 2013



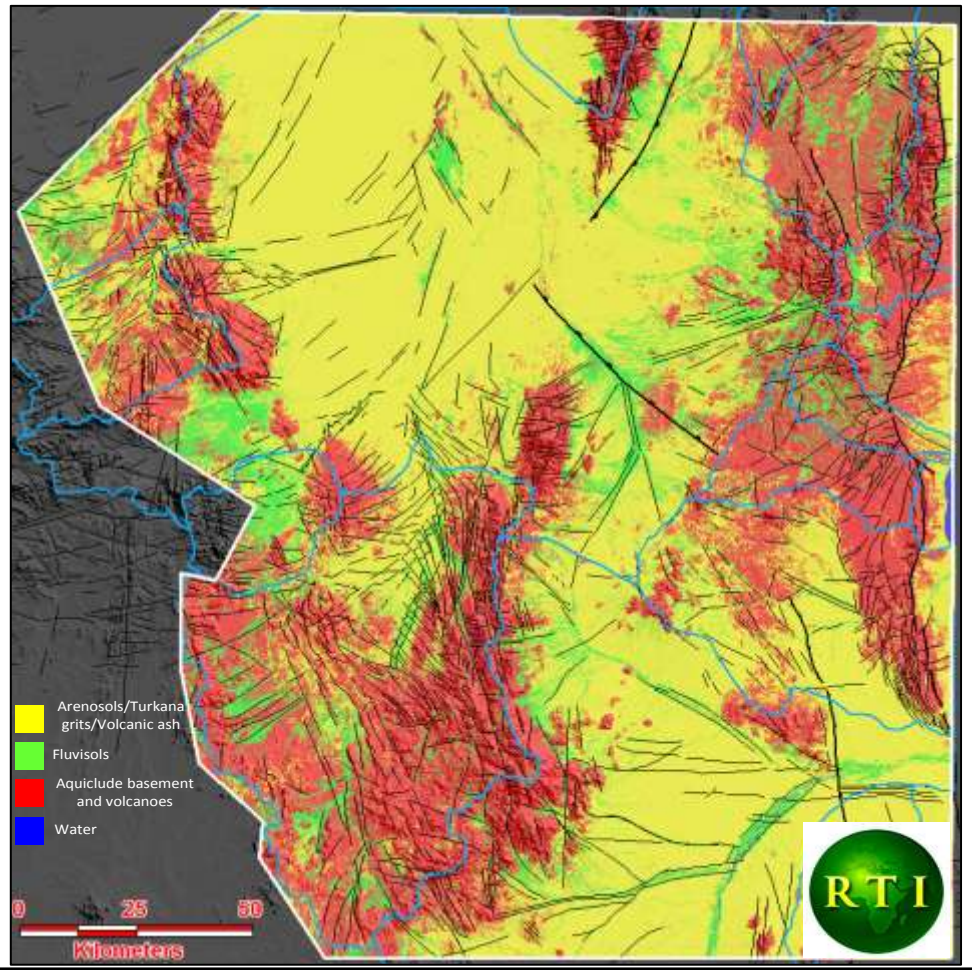
WATEX Fracture classification, Conductive (yellow), non-conductive (blue)



METHODOLOGY

WATEX Groundwater Recharge Mapping and Classification

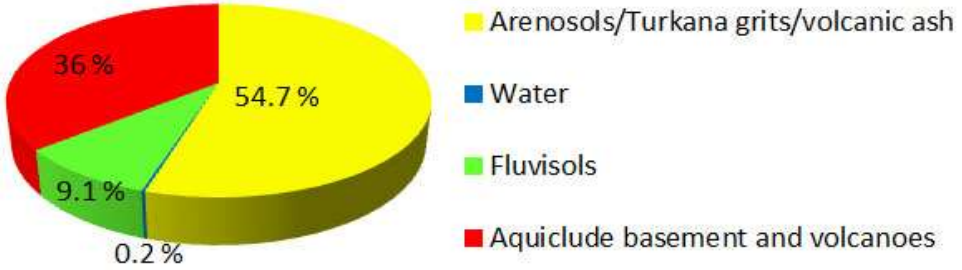
Regional groundwater recharge, RTI, 2013



Recharge classification, RTI, 2013

Recharge map legend.

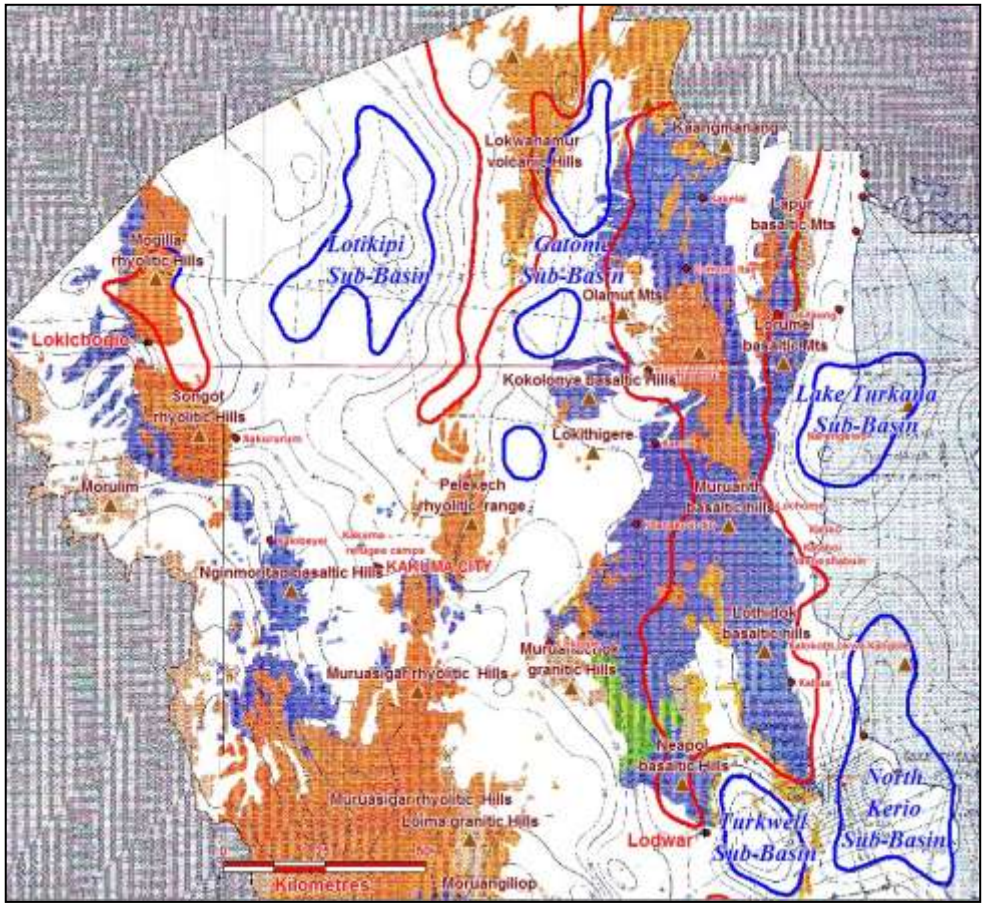
Intergranular recharge	Alluvial deposits : gravel, sand silt clay. Excellent recharge rate due to high Silica content from weathered basement porosity : 15 to 30%
Intergranular recharge	1-Arenosols from basement erosion 2-Sandy alluvial and windblown deposits 3-Piedmont regoliths 4-Turkana grits Paleogen and neogen sandstones 5-Volcanic ash deposits Global porosity : 30 to 35% vertical recharge
Fracturation	Conductivity of alluvial, cemented Turkana grits and volcanoclastic deposits increased by fractures
Aquiclude	1-Basement 2-Basaltic flows and rhyolitic formations Low to moderate porosity due to weathering



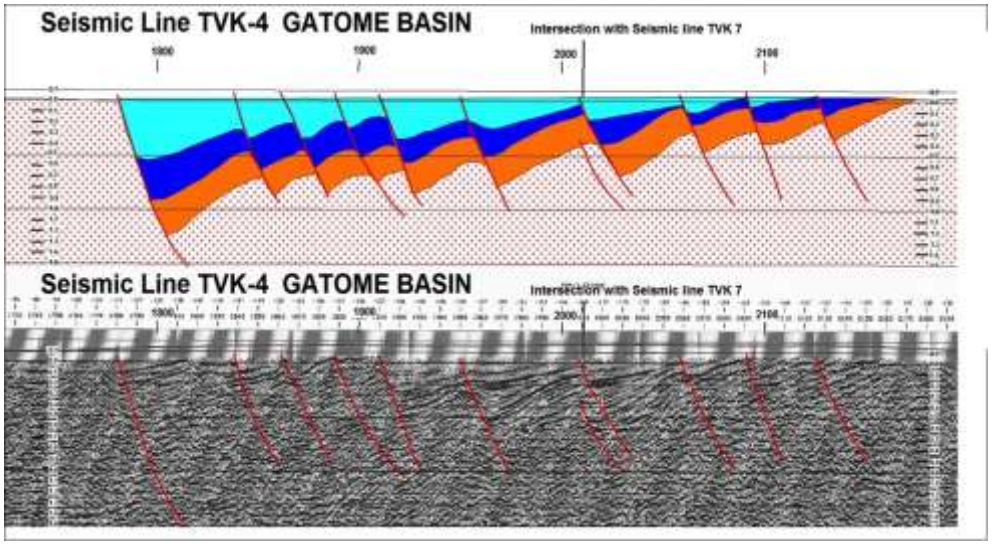
METHODOLOGY

WATEX Deep Aquifer Model (DAM):
Detecting deep-seated aquifers (100 -3,000 m)

Interpretation of gravimetric data, RTI, 2012



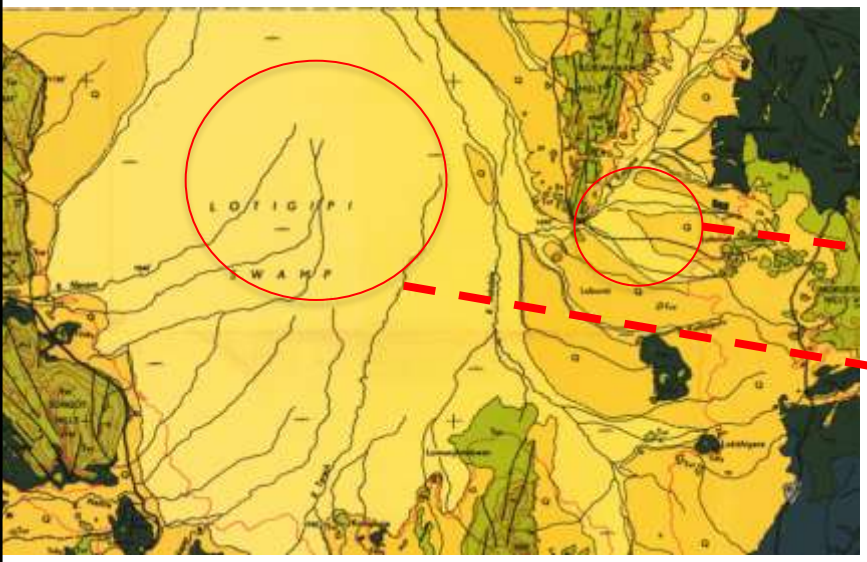
Interpretation of seismic data, RTI, 2012



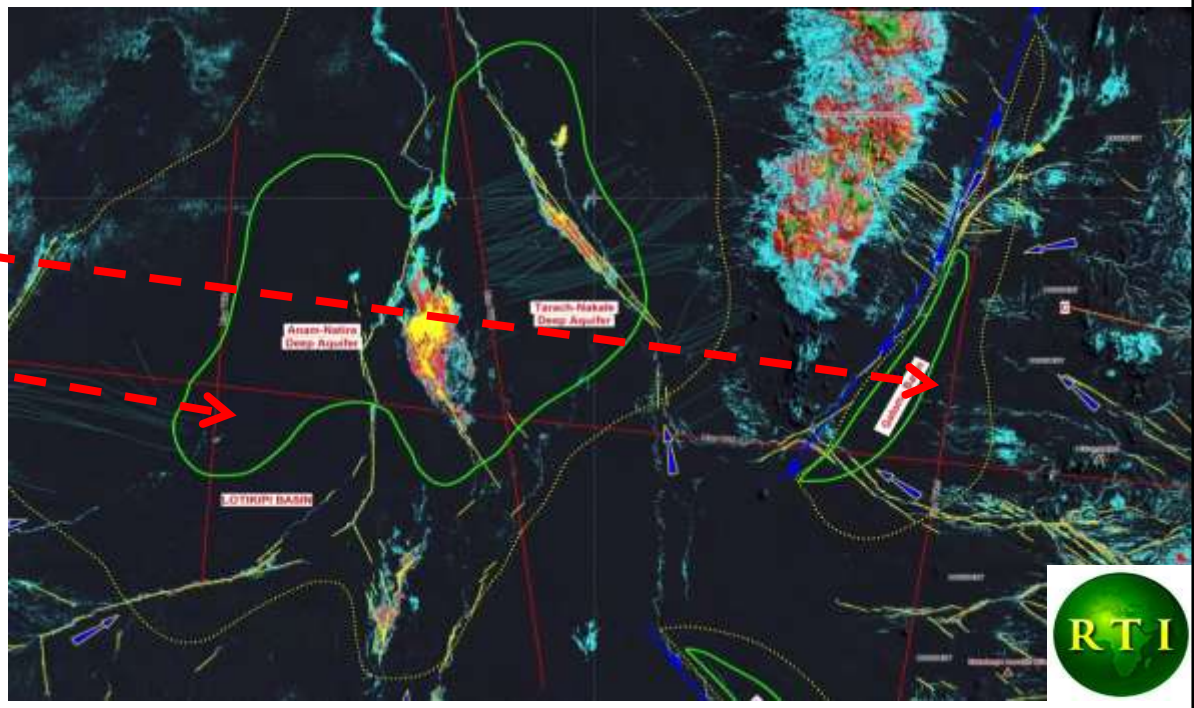
METHODOLOGY

WATEX Deep Aquifer Model (DAM):
Detecting deep-seated aquifers (100 -3,000 m)

Before: Outdated map, no aquifers shown, 1963



After: DAM representation of Gatome and Lotikipi Aquifers, RTI, 2013



METHODOLOGY

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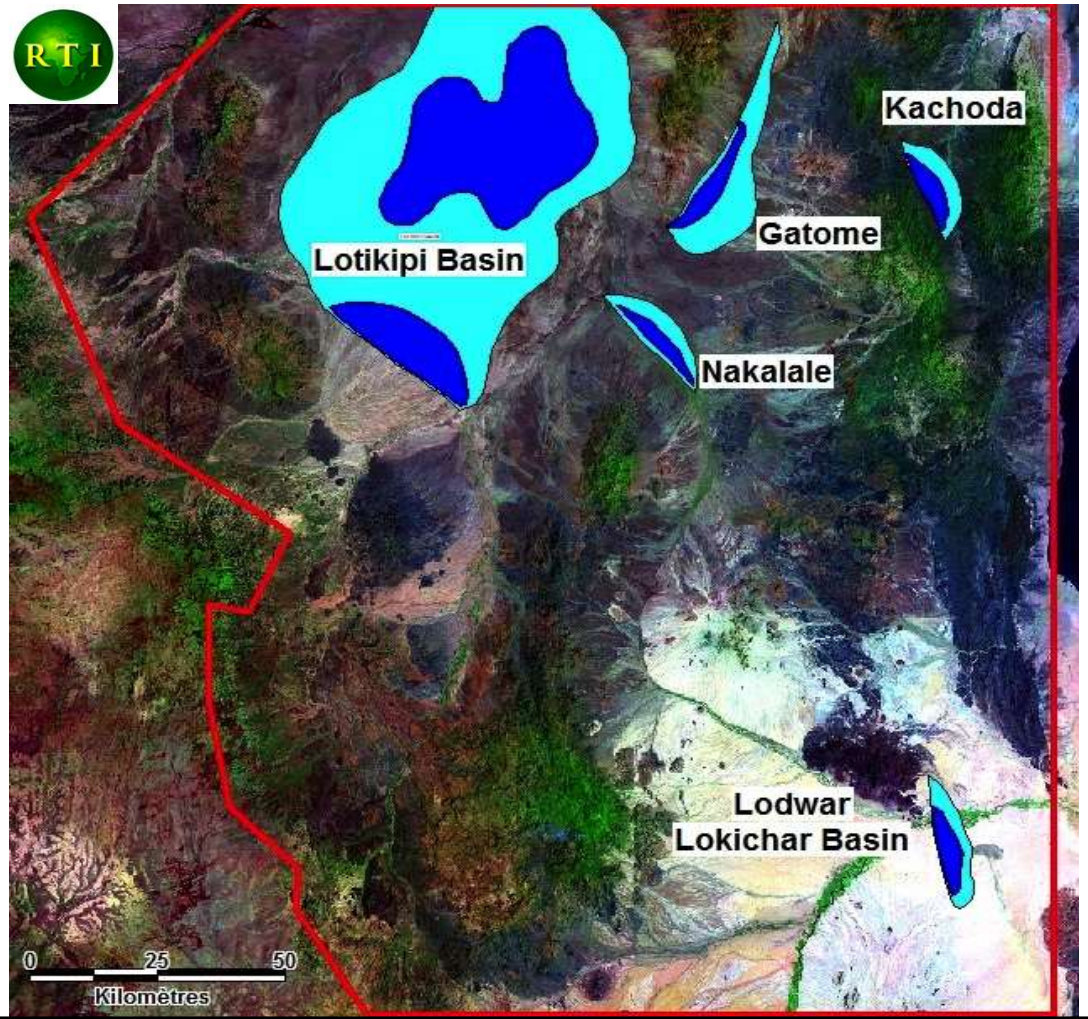
Detecting deep-seated aquifers (100 -3,000 m)

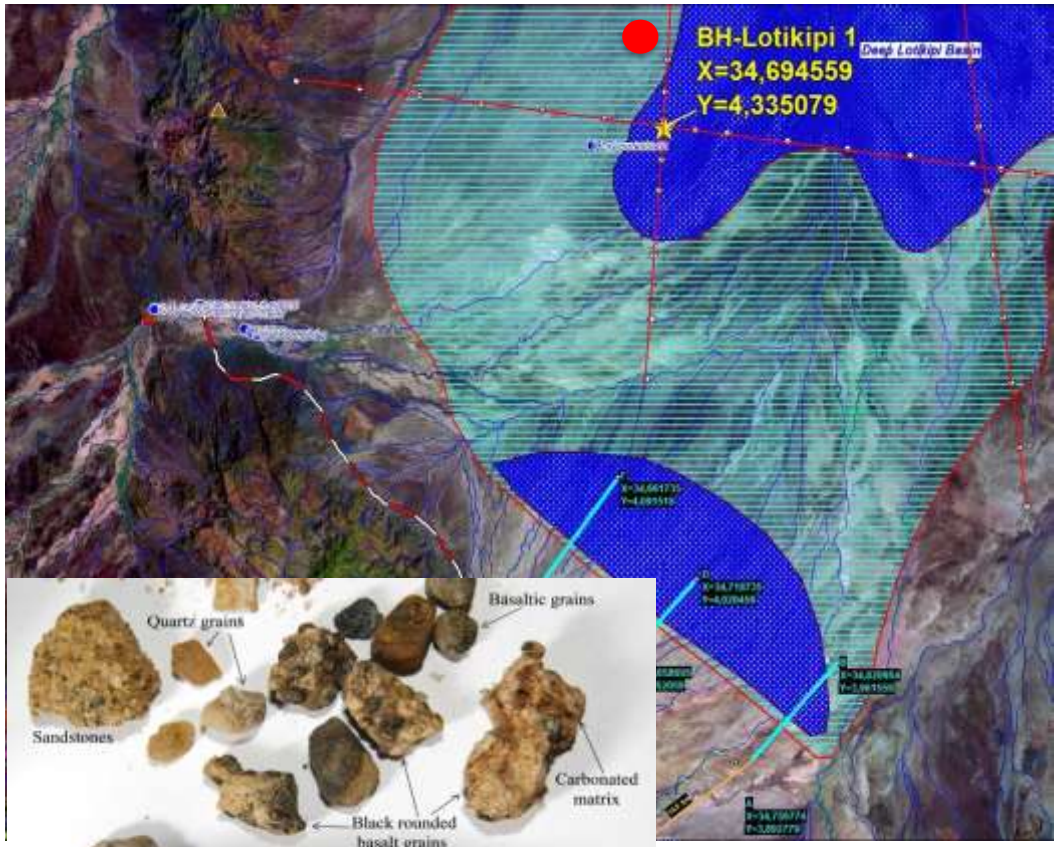
Regional deep aquifers, RTI, 2013



EXPLORATORY DRILLING

Lotikipi Basin Aquifer
(confirmed, July 2013)

Location of EX-BH-Lotikipi



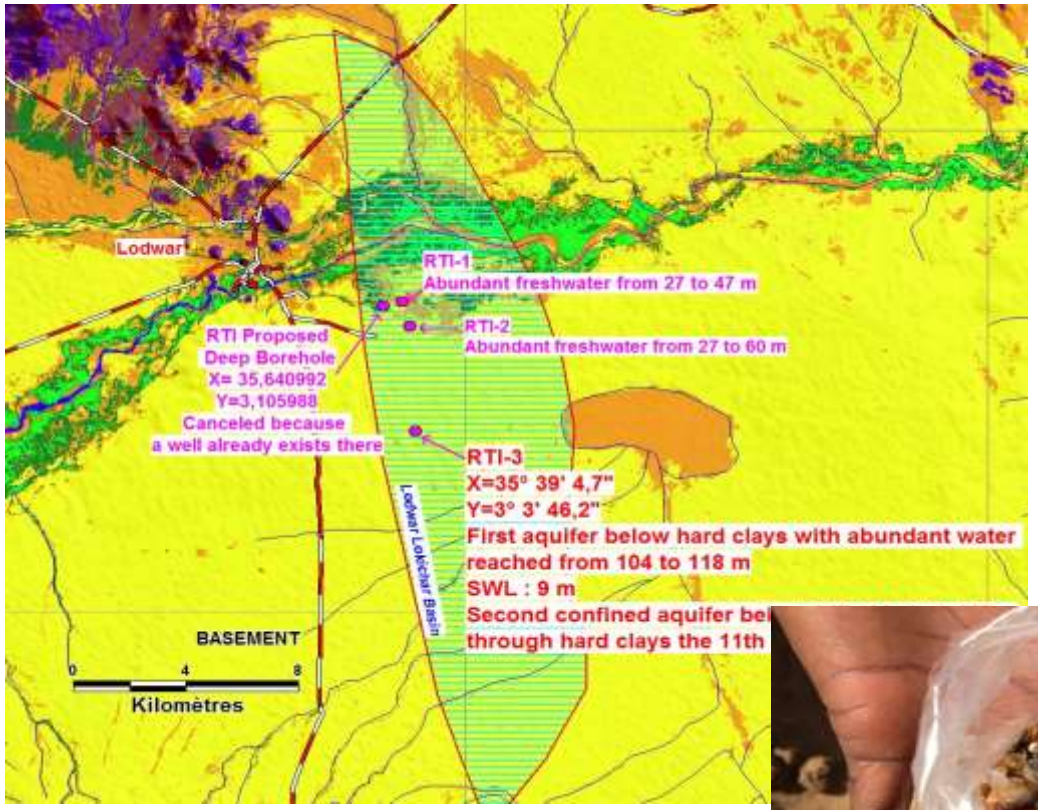
Cuttings from Lotikipi BH

Borehole testing and flushing

EXPLORATORY DRILLING

Lodwar Basin Aquifer
(confirmed, March 2013)

Location of EX-BH 1-3 Lodwar



Borehole testing and flushing, Lodwar BH 2

Cuttings from Lodwar BH

MODEL VALIDATION

WATEX accuracy level in Turkana: > 94% for shallow alluvial groundwater occurrence

UNESCO Validation Results

	Sample 1 Collected by RTI		Sample 2 Collected by UNESCO (Secondary sources)		Sample 3 Collected by UNESCO in the field		Sample 4 New boreholes drilled with the WATEX survey maps	
	Qty	%	Qty	%	Qty	%	Qty	%
SAMPLE ANALYSIS								
Sample size Total no. of water points (boreholes, wells and springs)	628		156		9		4	
No. of boreholes with groundwater occurrence	559	89%	146	94%	9	100%	4	100%
No. of boreholes with absence of groundwater	69	11%	10	7%	0	0%	0	0%
Test 1.: Level of model accuracy in detecting groundwater occurrence								
(A) No. of groundwater points with proven water occurrence (Total no. of PRODUCTIVE boreholes, wells and springs located in areas with positive WATEX response, eg. situated on a bright pixel)	395		94		9		4	
(B) No. of groundwater points which are situated on the positive response areas *Total number of NON-PRODUCTIVE and PRODUCTIVE boreholes, wells and springs located in areas with positive WATEX response (situated on a bright pixel*	421		97		9		4	
(C) Level of model accuracy (skill) in detecting the occurrence of water in positive response areas *Proportion (%) of productive boreholes, wells and springs to total number of non-productive/productive boreholes, wells and springs which are located in areas with positive WATEX response (situated on a bright pixel). Formula: C = A / B x 100*		94%		97%		100%		100%

RESULTS AND FINDINGS

Total Groundwater Resources in Northern-central Turkana County

Aquifer regime	Est. Recharge (MCM / yr)	Est. Storage Capacity (MCM)
Shallow alluvial systems (0-100 m)	2,085	2,085*
Deep-seated systems (100-800 m)	1,362	248,250
	3,447	250,335

* In absence of localized data at the regional scale, a conservative estimate for the cumulative storage capacity of shallow alluvial assumes the same amount of annual recharge

RESULTS AND FINDINGS

Shallow Alluvial Groundwater Systems in Northern-central Turkana County

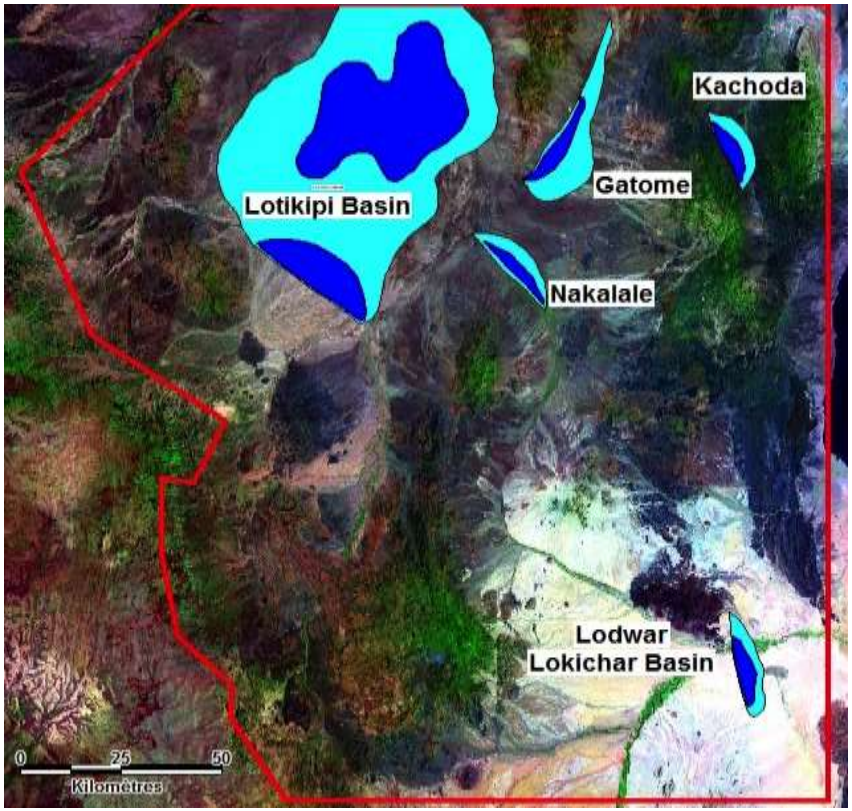
Shallow Alluvial Aquifer Units (Superficial, intra-volcanic systems)	Surface area (km2)	Rainfall harvested (MCM/yr)	Recharge (MCM/yr)	Storage capacity (MCM)
Lotikipi Basin watersheds				
(1) Kakuma on River Tarash	5,168	2,217	361	-*
(2) Lokichogio on Napas River	1,313	658	107	-*
(3) Kalobeiyei	770	293	48	-*
Lake Turkana Basin watersheds				
(4) Turkwel-Lodwar	16,516	7,925	1,292	20**
(5) Kalokol	2,682	804	131	-*
(6) Katabol	769	230	37	-*
(7) Lochome	423	130	21	-*
(8) Eturin	336	100	16	-*
(9) Lomogoi	1,465	439	72	-*
		Total	**2,085**	-*

* Not estimated due to insufficient data of the complex inter-basaltic systems.
** Within a radius of 10 km of Lodwar town.

RESULTS AND FINDINGS

Deep-seated Aquifer Systems in Northern-central Turkana County

Aquifer system	Recharge (MCM/yr)	Storage capacity (MCM)
(1) Lotikipi Basin	1,200	207,500
(2) Lodwar Basin	-*	10,000
(3) Gatome Half-graben	61	17,250
(4) Nakalale Half-graben	59	7,000
(5) Kachoda Half-graben	21	6,500
Total	**1,362**	**248,250**



* Estimate for recharge of Lodwar Aquifer is not given due to insufficient data on Turkwel River recharge dynamics.

RESULTS AND FINDINGS

Groundwater Potential for Priority Areas in Northern-central Turkana County

Lodwar

- Groundwater potential (1,292 MCM per year)
- No seasonal groundwater level variation in the boreholes below alluvial deposits
- Endowed with the deep Lodwar Basin Aquifer (10 BCM)

Kakuma

- Groundwater potential, within 10km2, (51 million m3/year
- Current water withdrawals only 2.5% of available groundwater
- Best options for shallow boreholes (<100 meters) is to drill within the fracture corridor of the Tarash River identified by the study
- Located 25 km south of the southern portion of Lotikipi Basin Aquifer

RESULTS AND FINDINGS

Groundwater Potential for Priority Areas in Northern-central Turkana County

Kalobeiyei

- Groundwater potential (48 MCM/yr)
- Too dispersed and fragmented
- Poor local conditions to support a new population of refugees
- Located 25 km west of the southern portion of Lotikipi Basin Aquifer

Lokichogio

- Groundwater potential, (107 million m3/year
- Few viable options available within 10 km of town
- Located 25 km west of the western portion of Lotikipi Basin Aquifer

DEVELOPMENT POTENTIAL

Current development indicators in Kenya	
A. Kenya population, 2011	41 million
B. Population lacking access to safe water[3]	17 million (43%)
C. Population lacking adequate sanitation[4]	28 million (68%)
D. Poverty rate[5]	20 million (50%)
E. Total renewable water resources[6]	20.2 km3 / year (4.8 mi3)
F. Total renewable water resources per capita[7]	647 m3 / year (22,848 ft3/yr)
G. Projected total renewable water resources per capita, 2025[8]	235 m3 / year (8,299 ft3/yr)
H. Total water withdrawals per capita[9]	87 m3 / year (3,072 ft3/yr)
I. National storage capacity, all dams[10]	24.78 km3 (5.9 mi3)
Development potential of groundwater resources in N-C Turkana, as surveyed	
A. Percentage of the total renewable water resources (Kenya)	17%
B. Increase in the share of water available per capita (Kenya)	83 m3 / year / per person (2,931 ft3/yr/pp)
C. Population that could be served annually by recharge (all economic sectors)[11]	39.4 million
D. Population that could be served annually by recharge (humanitarian only)[12]	625 million
E. Aquifer longevity (depletion period)[13]	70 years
F. Population that could be served by storage reserve until depletion[14]	2.9 billion (@ Kenyan consumption rate) 158 million (@ US consumption rate)

RECOMMENDATIONS

Use of survey tools and maps

- The Government of Kenya should take measures to ensure the dissemination of information and tools to stakeholders
- GOK, UNESCO and other partners should expand and build the cadre of skilled professionals who can utilize the survey tools

RECOMMENDATIONS

Continued research

- Kenyan government and other research institutions (eg. University of Nairobi) should conduct additional studies in order to achieve a more comprehensive understanding of these resources and their full potential and vulnerabilities
- Expand the WATEX study approach to the rest of Kenya in order to benefit other regions. Turkana can be a model for other counties
- Study the socio-economic potential of groundwater, particularly the deep aquifers.
- Continue hydrogeological research and modeling of deep structures, including the exploration of the un-confirmed structures

RECOMMENDATIONS

Build national drilling capacities

- The skills and capacity of the Kenyan borehole drilling industry are inadequate for carrying out reliable and sound exploratory drilling, and need to be supported to improve the level of capacity and service. The industry is short in terms of skilled professionals and in terms of equipment, which is outdated. The impact is felt when many drilling projects do not succeed due to lack of capacity.
- A major campaign should be launched to build the capacity of the industry as a whole, and reduce the inefficiencies in the market.

RECOMMENDATIONS

Short-term development projects

- Develop exploratory boreholes (Lotikipi and Lodwar) to be able to provide immediate water supply to local communities

- Drill up to 200-500 shallow alluvial boreholes in high-potential areas identified by this survey

RECOMMENDATIONS

Aquifer management

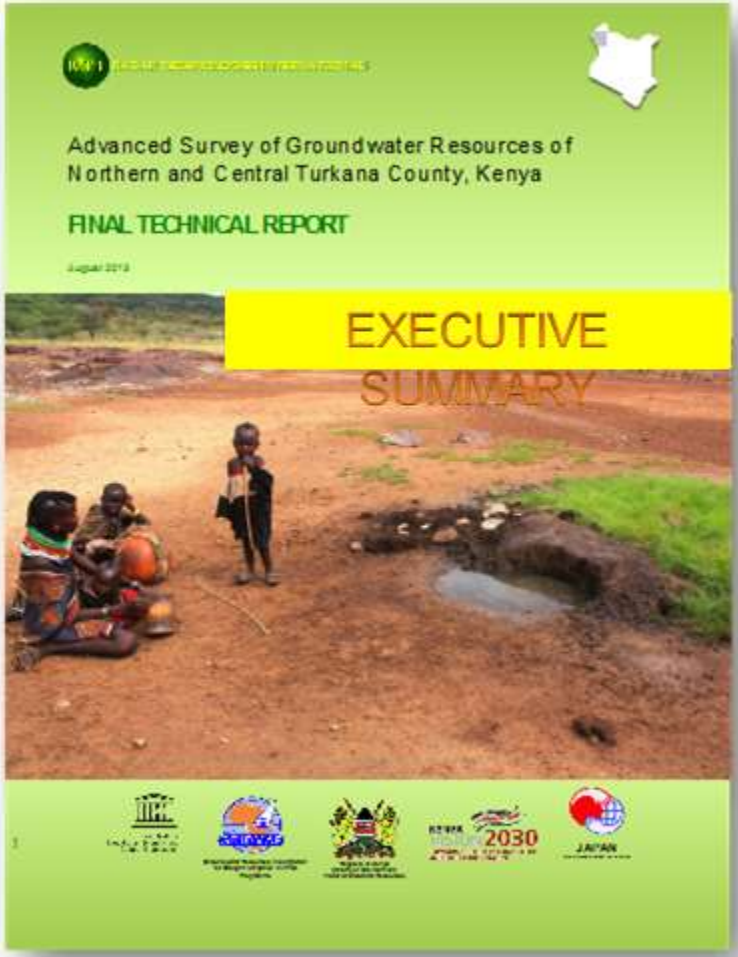
- Kenyan authorities should establish a limit on abstraction rates for both the Lotikipi and Lodwar Aquifers. WRMA can establish the rates for abstraction for normal and emergency situations
- Kenyan authorities are recommended to gazette the land above the aquifers in order to protect them from harmful activities.
- Establish a modern aquifer monitoring system to monitor the Lotikipi and Lodwar aquifers.

SURVEY PRODUCTS

Reports and Analysis

Full Technical Report (August 2013)

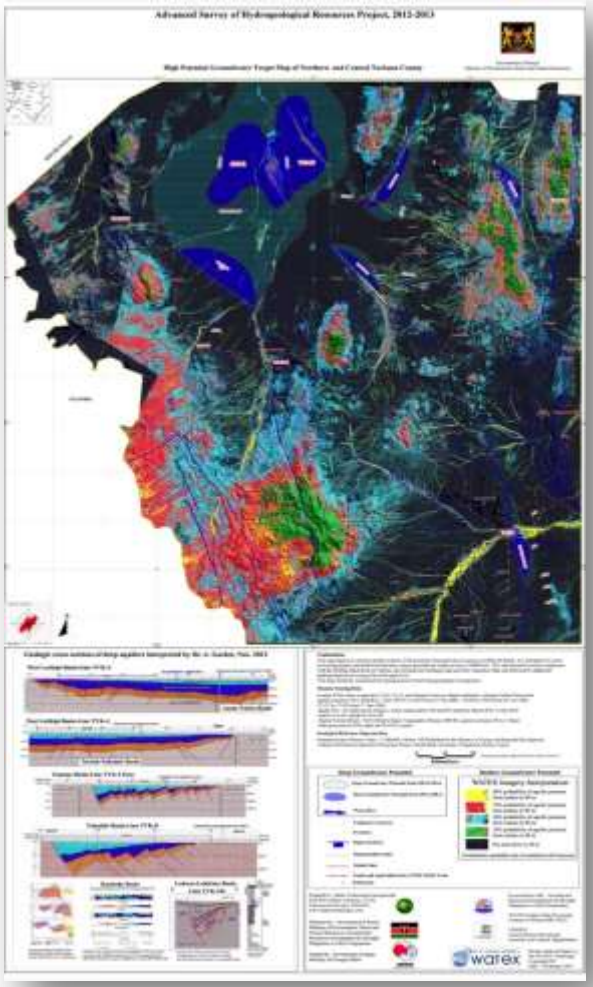
Executive Summary



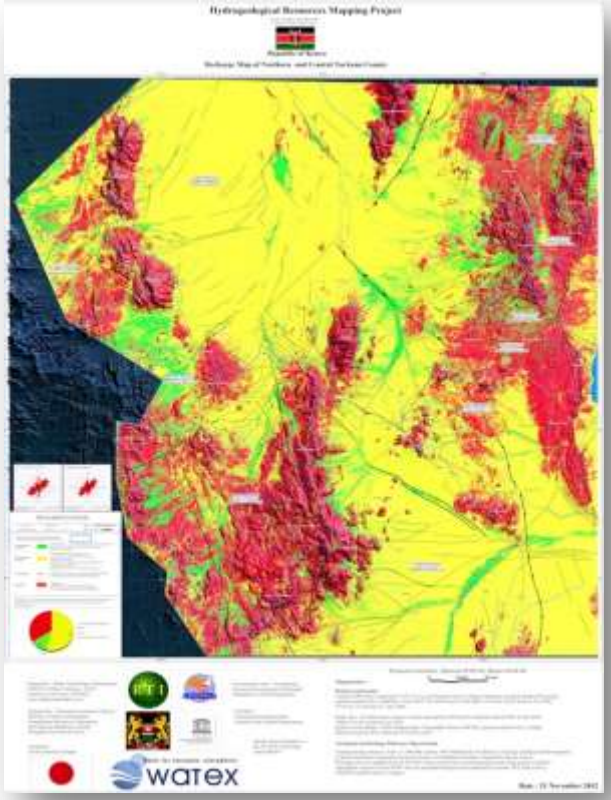
SURVEY PRODUCTS

Standardized Maps

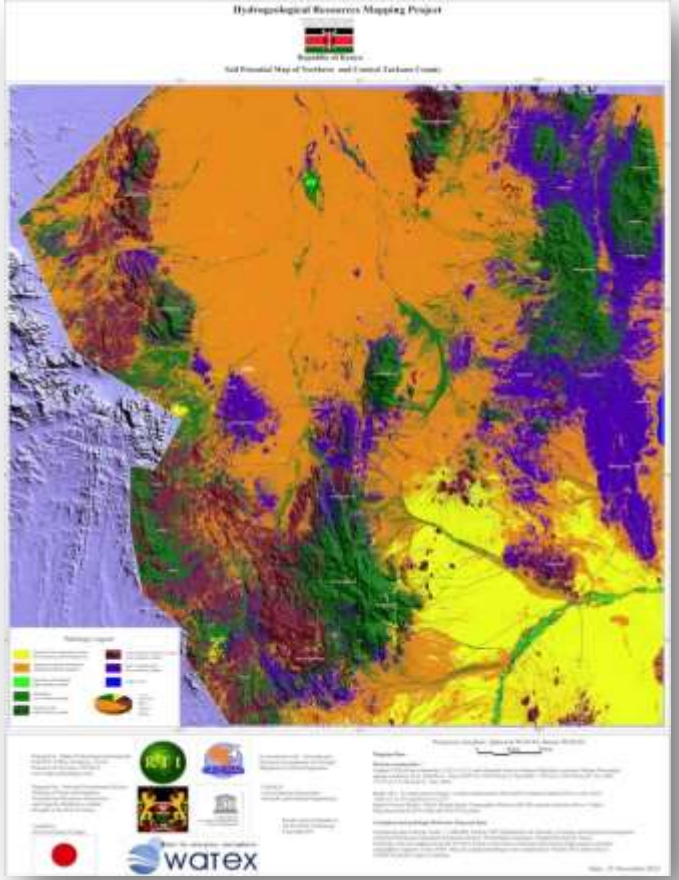
High Potential Groundwater Target Map (1:200,000)



Groundwater Recharge Map (1:200,000)



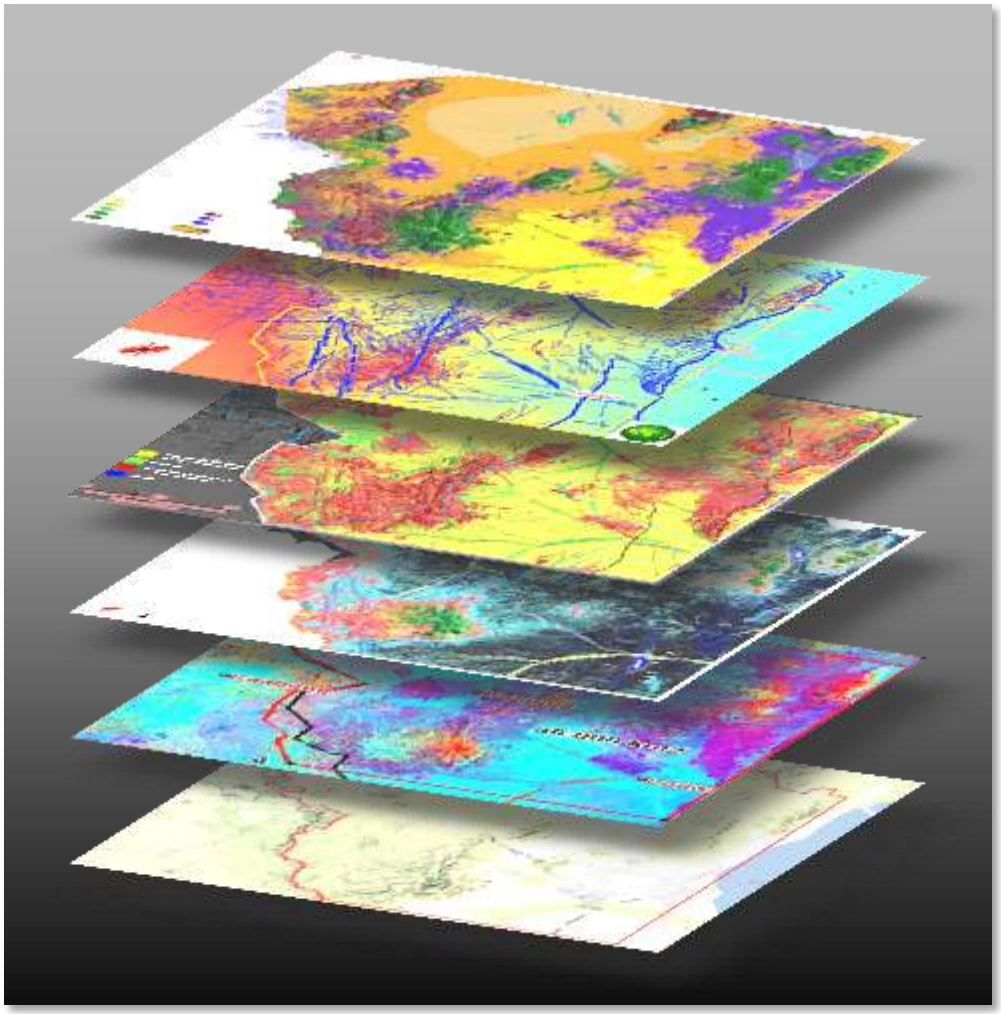
Soil and Vegetation Recharge Map (1:200,000)



SURVEY PRODUCTS

Groundwater Management Tools

GIS Database of Groundwater Resources



Groundwater Exploration Navigation System (GENS)

SURVEY PRODUCTS

Groundwater Management Tools

Technical Field Manual for Groundwater Targeting (July 2013)

Field Training of Kenyan Experts and Technicians

This survey is dedicated to the people of Turkana