Hydrogeological Mapping for Climate Resilient WASH in Ethiopia – LOT 1

21 March 2022

Phase 3 Validation

BDA/ICB/GW01/2021

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MINISTRY OF WATER AND ENERGY

ACACIA WATER

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Content

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- Challenges Phase III
- Examples of target areas
- Second7 data
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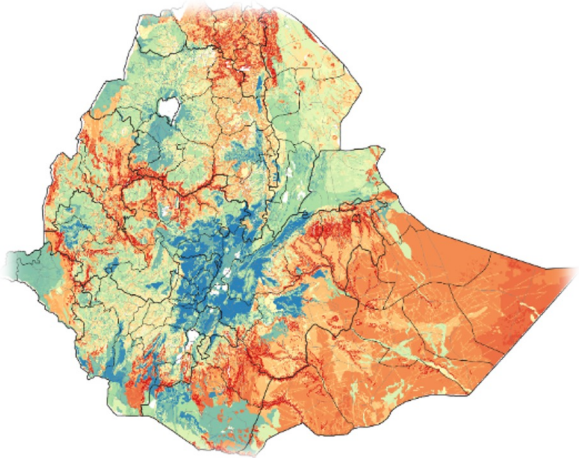
- Recharge, water use and Resilience

Project Objectives

Increase access to safe and sustainable water for the people in drought affected regions by:

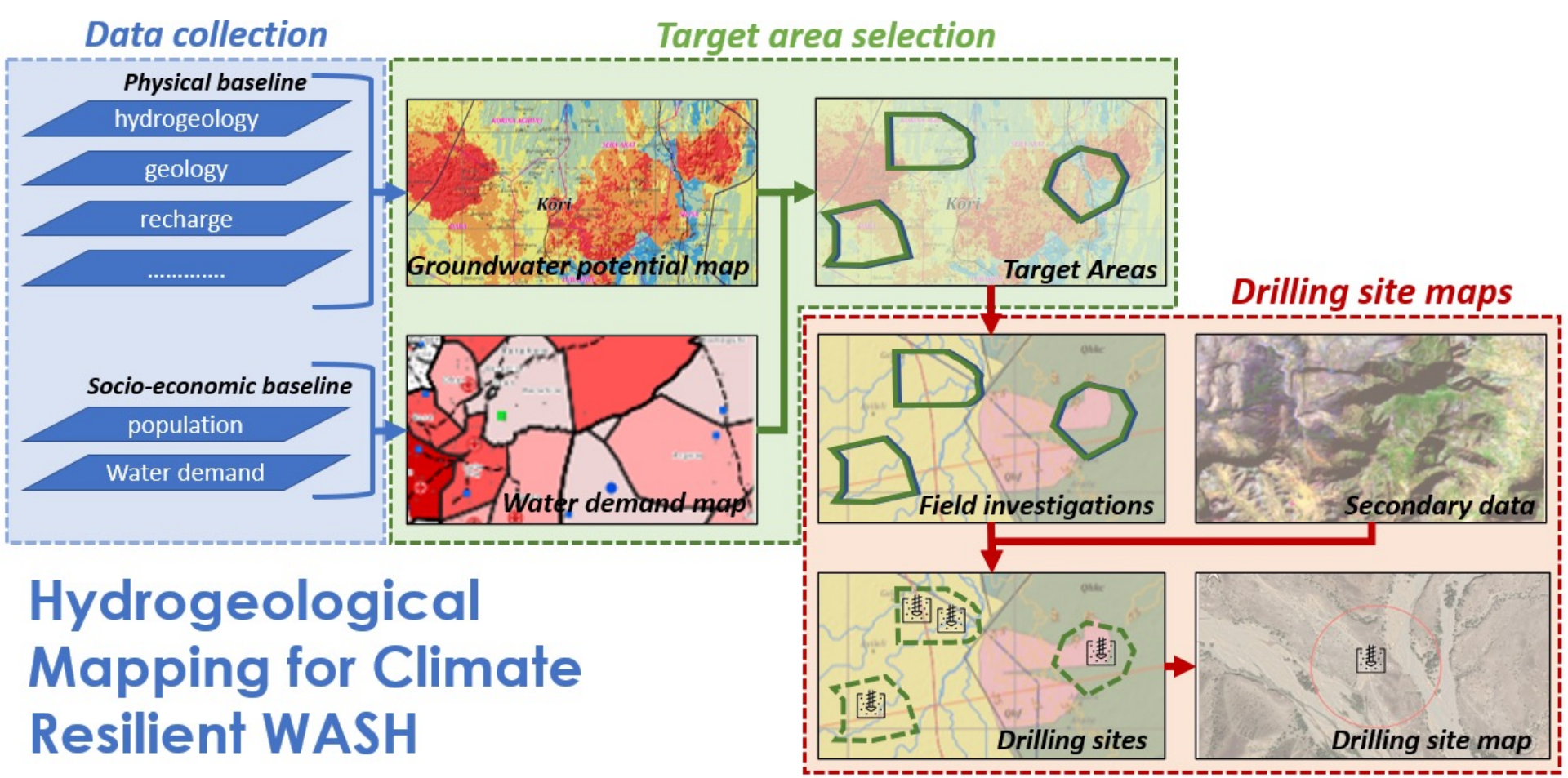
1. producing hydrogeological maps at the Woreda level and
2. recommend drilling sites for developing groundwater



Project Objectives

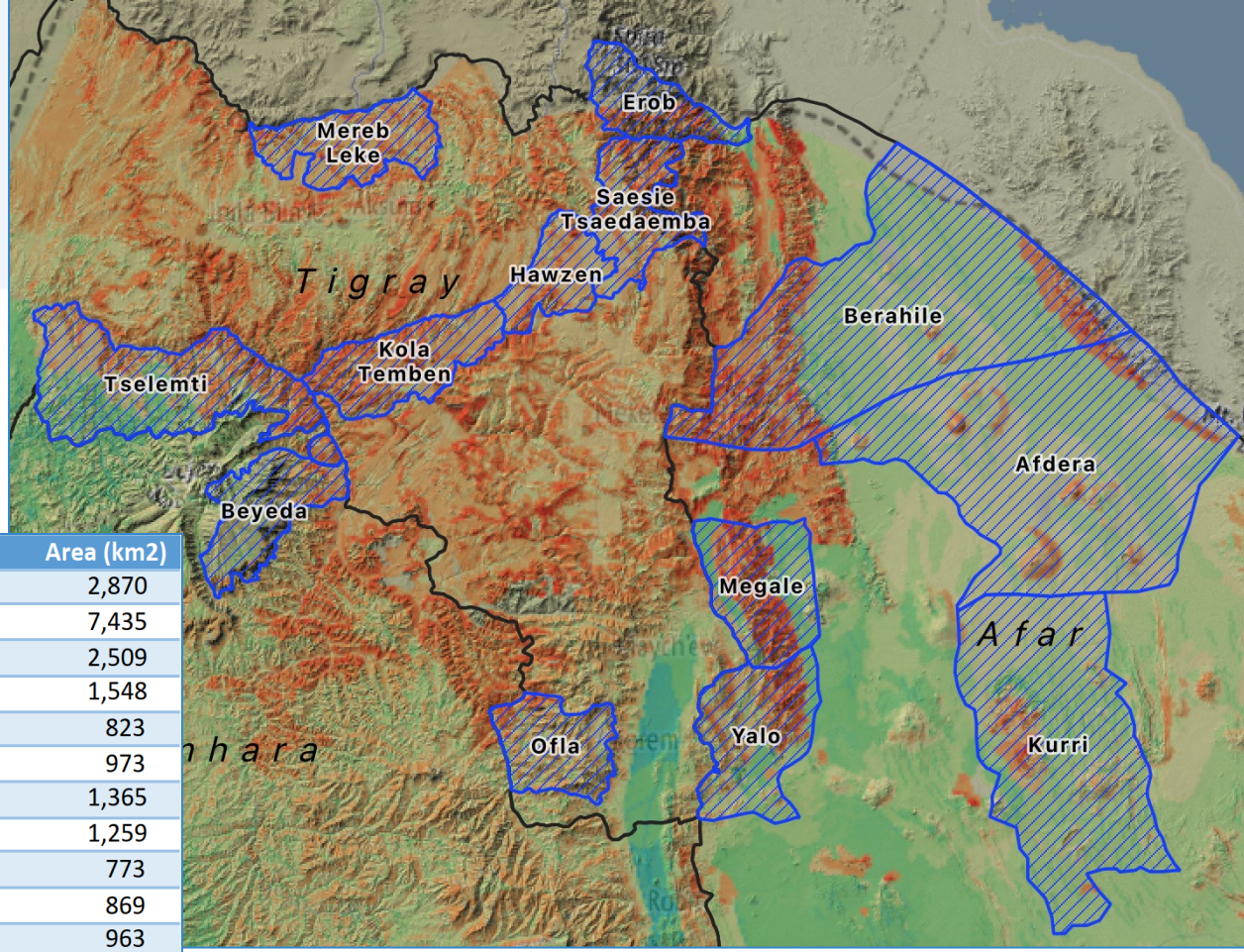
Specific objectives

1. Create detailed groundwater potential maps for each Woreda.
2. Identify two optimal drilling sites per Woreda
3. Recommend the type of drilling methodology(s) to be employed
4. Build the capacity for stakeholders to use/apply overlay analysis techniques for groundwater potential mapping and borehole siting

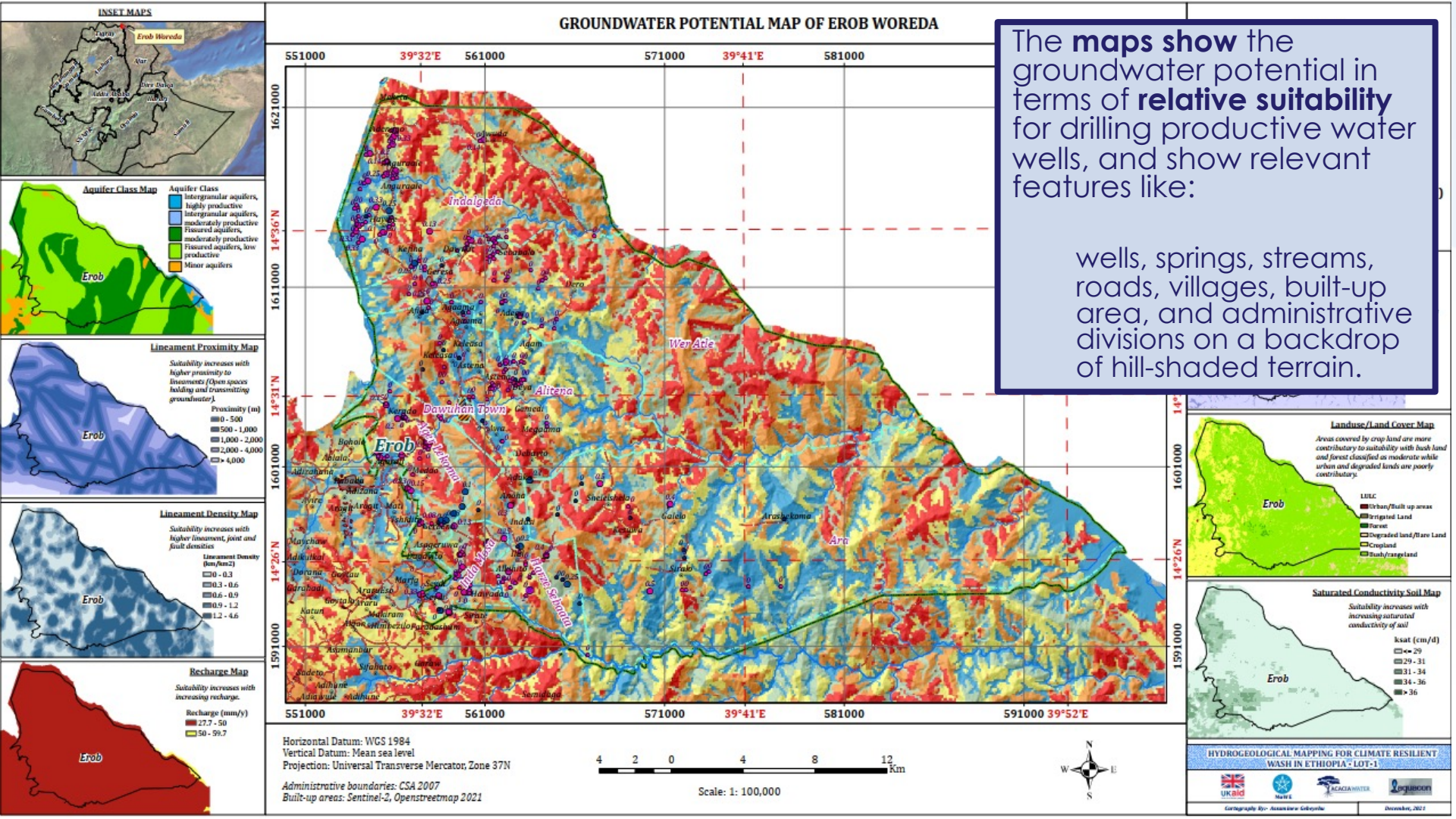


Hydrogeological Mapping for Climate Resilient WASH

Project Area
LOT 1



Region	Zone	Woreda	Area (km2)
Afar	Zone 1	Kurri	2,870
Afar	Zone 2	Afdera	7,435
Afar	Zone 2	Berahile	2,509
Afar	Zone 2	Megale	1,548
Afar	Zone 4	Yalo	823
Amhara	North Gonder	Beyeda	973
Tigray	Central	Kola Temben	1,365
Tigray	Central	Mereb Leke	1,259
Tigray	Eastern	Erob	773
Tigray	Eastern	Hawzen	869
Tigray	Eastern	Saesie Tsaedaemba	963
Tigray	Northwestern	Tselemti	2,656
Tigray	Southern	Ofla	1,085
		Total	**25,128**



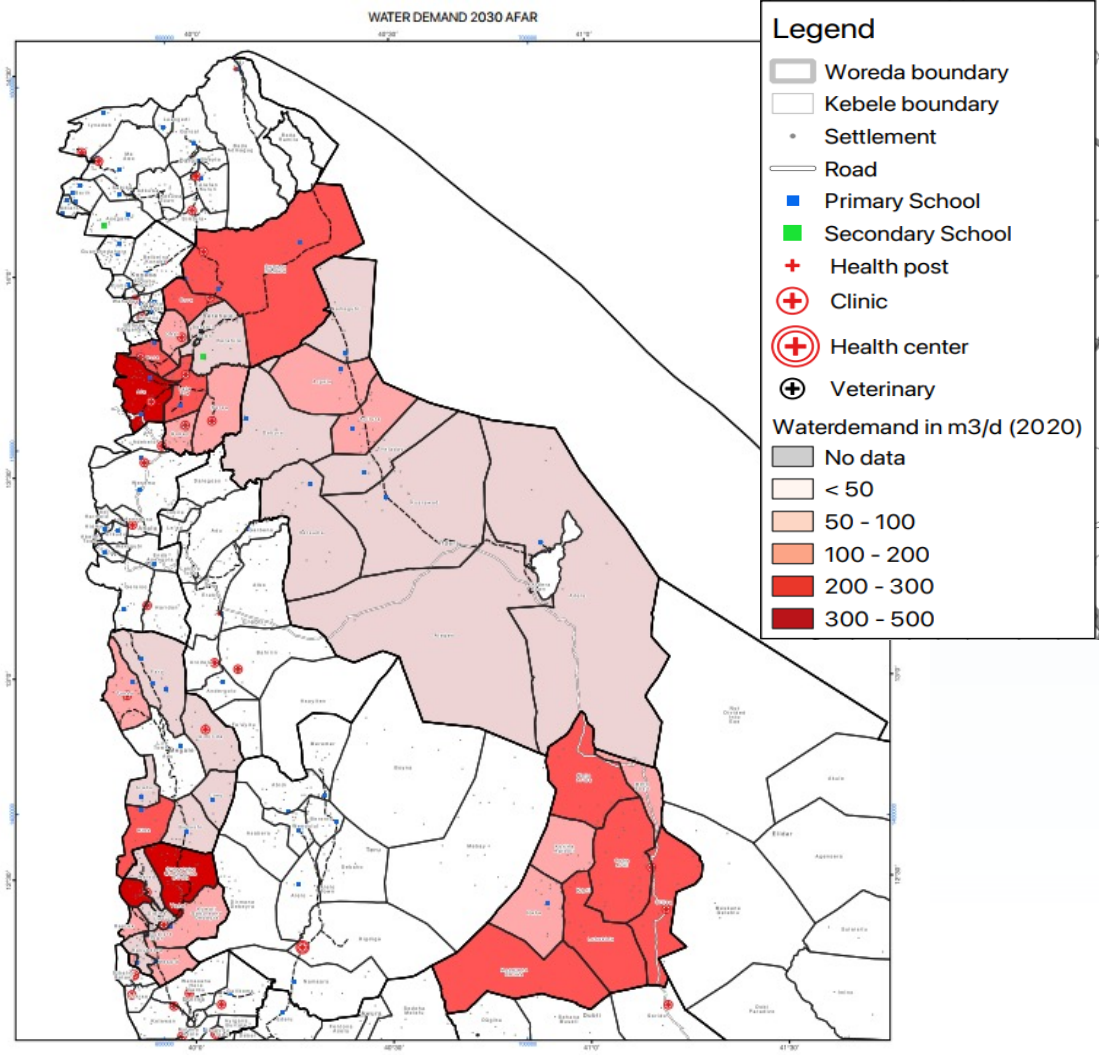
The **maps show** the groundwater potential in terms of **relative suitability** for drilling productive water wells, and show relevant features like:

wells, springs, streams, roads, villages, built-up area, and administrative divisions on a backdrop of hill-shaded terrain.

AFAR

Data Sources and assumptions:

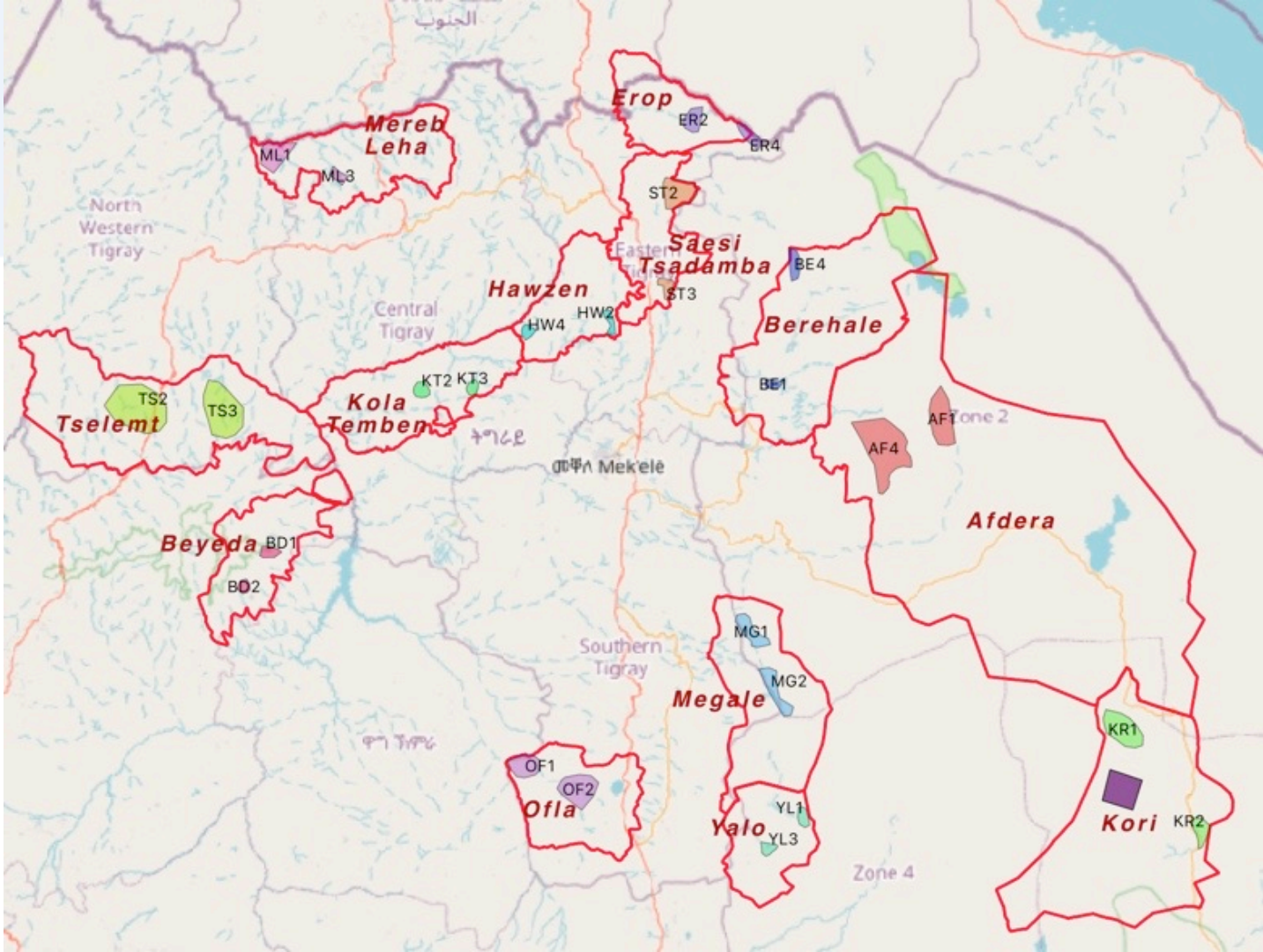
- **Population data:** based on the census 2007 data (CSA, 2017, 2019), estimated for 2030
- **Livestock**: estimated from zonal data 2007
- **Water demand:**
  - Drinking
  - Livestock



Target area; 26 in total

Criteria:

- Potential
- Demand



Phase III

The main deliverables

- For each **26** target area
  - Hydrogeological study / Conceptual model
  - Geological study
  - Geophysical survey
- **42** drilling sites
- Well design and technical specifications
- Hydrology (SWAT Water balance modeling)
- Groundwater Risk Mitigation Strategy
- Training on GIS/RS

Field surveys not possible due to access restrictions

Alternative approach
- secondary data
- Expert judgement
- High resolution satellite imagery
- Airborne geophysics
- Climate resilience

Team of experts – Phase III

Topic	Expert
Geology	Dr. Tarekegn Tadesse Dr. Yohannes Degu Jiri Sima
Hydrology	Dr. Sirak Tekleab Gebrekristos Dr. Maarten Waterloo
Hydrogeology Tigray	Dr. Dessie Nedaw
Hydrogeology Afar/Amhara	Shiferaw Lulu
Geophysics	Dr. Shimeles Fisseha
Well design/mitigation strategy	Vince Uhl
GIS	Assaminew Gebeyehu Ashish Daw
Training GIS/RS	Prof. Dr. Maarten Waterloo Theo Kleinendorst Laurens de Vries
Project management	Zenaw Tessema Dr. Arjen de Vries

Training program

Day	Program of activities (AM/PM)
Day 1 *Tue., March 22nd*	Introduction to overlay analysis & QGIS / Input data processing (lithology, land use)
Day 2 *Wed., March 23rd*	Input data processing (recharge, TWI) / Input data processing (lineament proximity & density)
Day 3 *Thu., March 24th*	Suitability map generation / Automation of suitability mapping
Day 4 *Fri., March 25th*	Suitability map styling / Introduction to Google Earth Engine
Day 5 *Sat., March 26th*	Introduction to Python

Drilling site selection

How to select drilling sites

- Hydrogeological assessment
- Geological assessment
- Geophysics
- Supported by
  - Expert judgement
  - Secondary data

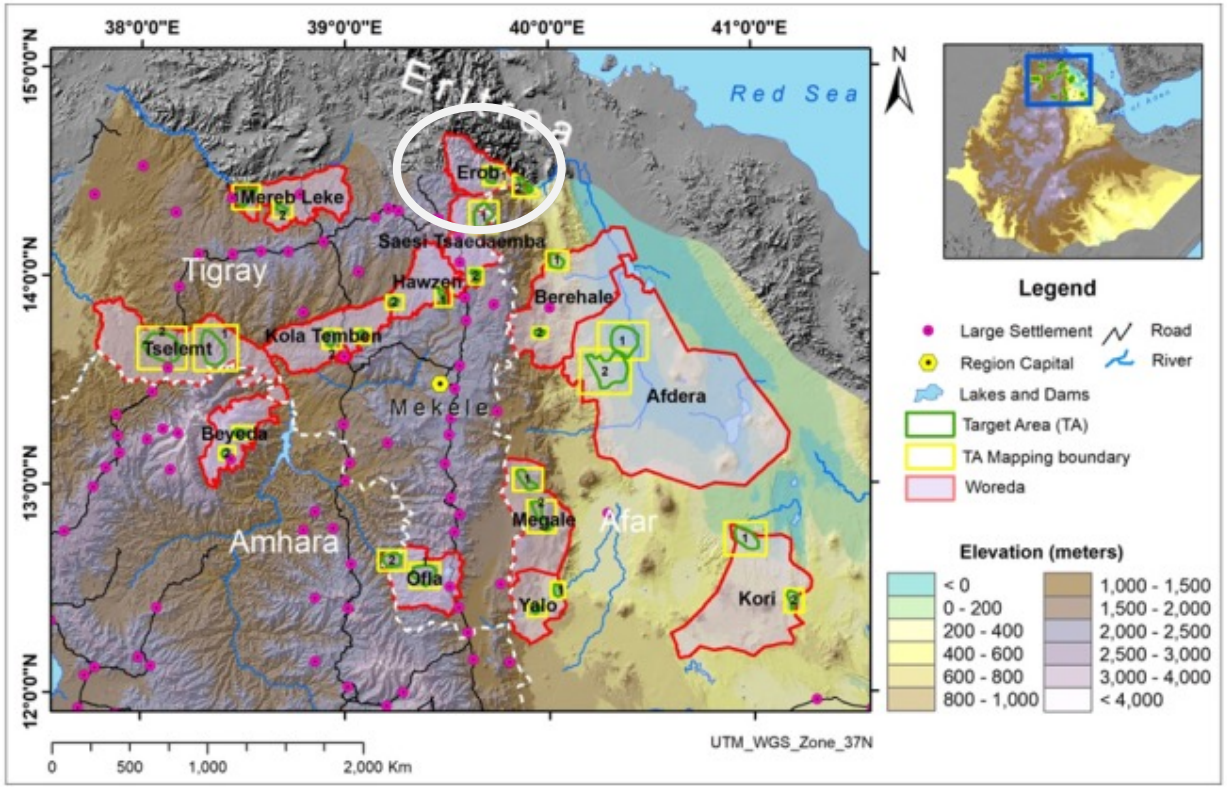
Multidisciplinary approach

Close communication between different experts crucial

Examples of target site analyses

- *Tigray* *Erob Target Area 1*
- *Afar* *Afdera Target Area 1*

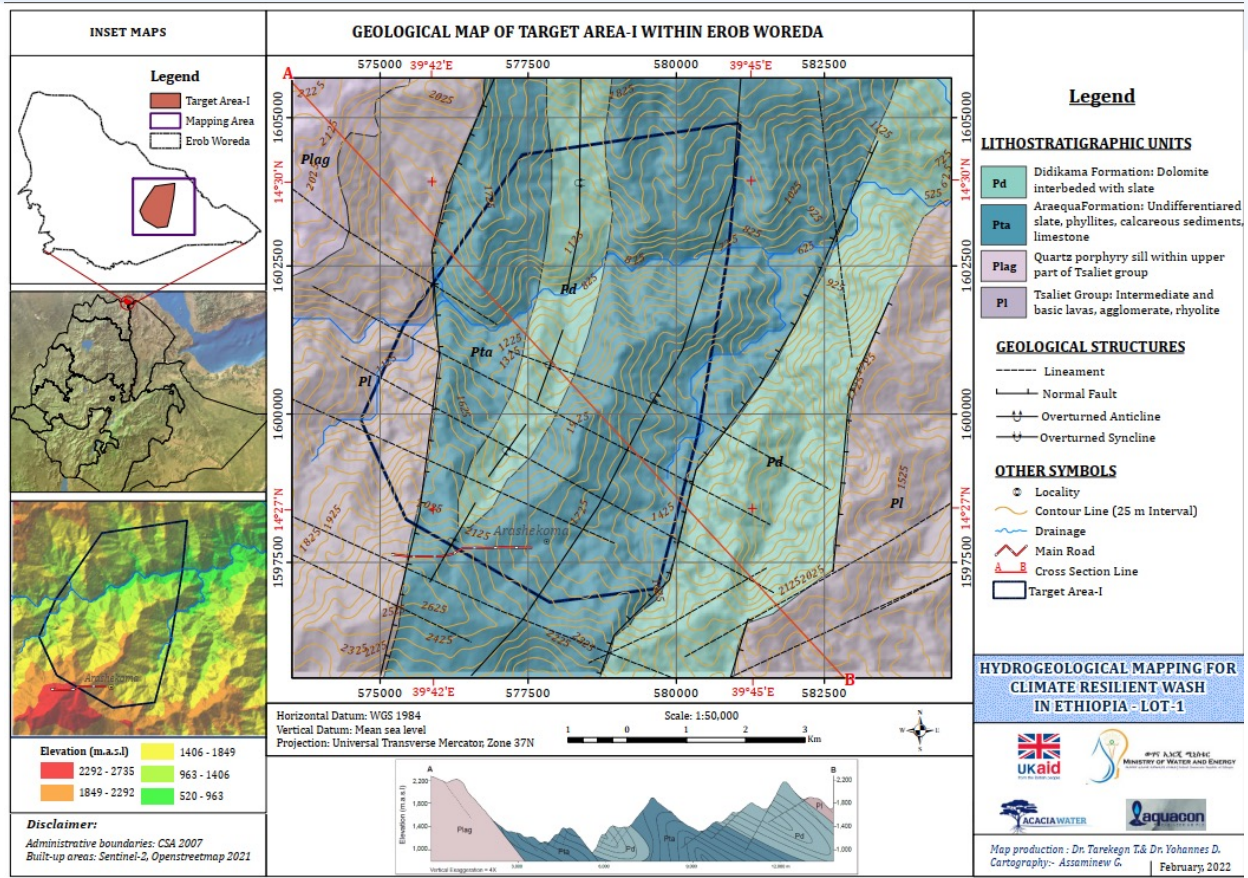
Tigray – TA Erob



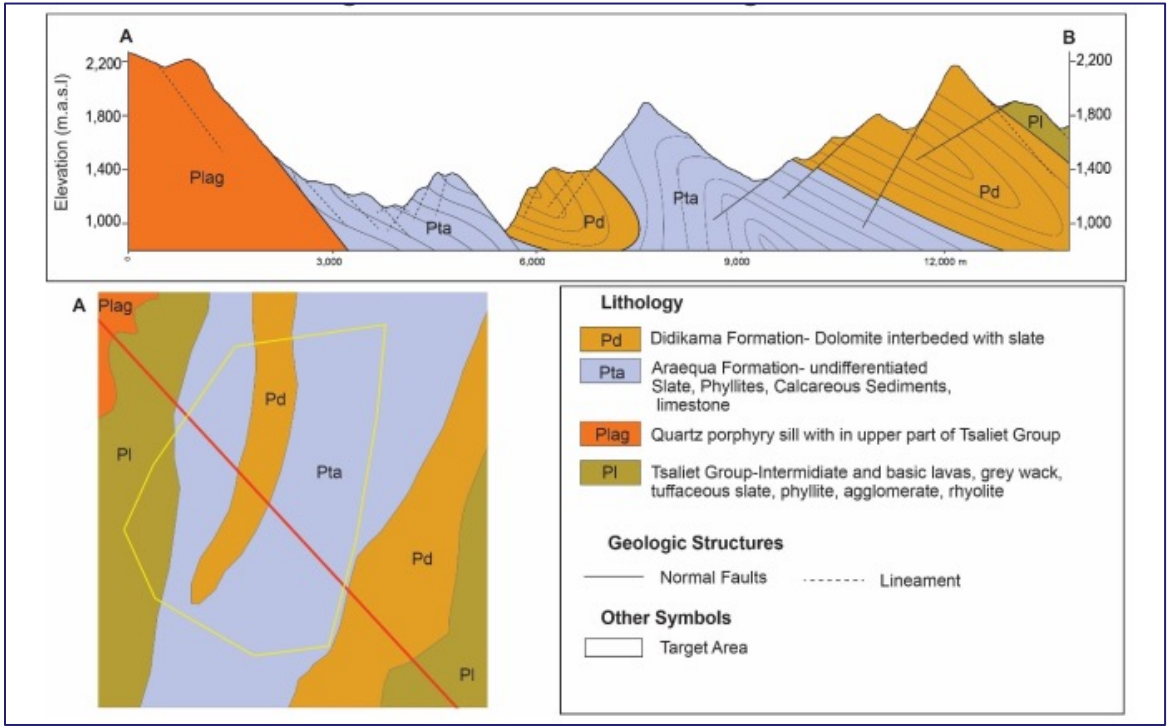
Erob TA1 – Hydrogeological characteristics

SN	Target Area code	Region	Zone	Woreda	Kebele	Center X	Center Y	Area (km^2)
1	ER2	Tigray	Eastern Tigray	Erob	Ara	578324	1601243	35
Moderately productive fissured aquifers developed in carbonate rocks of basement along perennial rivers and faults and lineaments. Development of aquifers can be done by drilling mainly shallow wells with depth about 100 m. Groundwater is medium hard with TDS above 1,000 mg/l and no ions exceeding standards for drinking.								

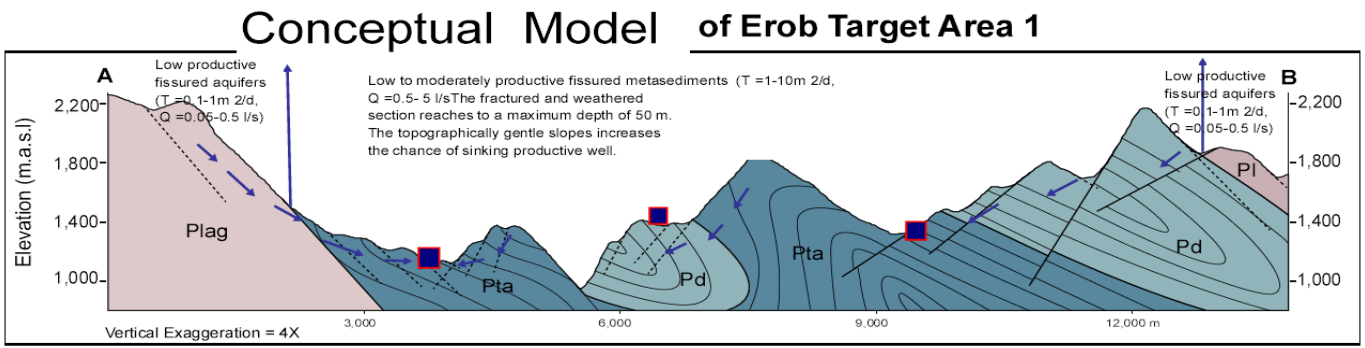
Erob TA1 – geological map

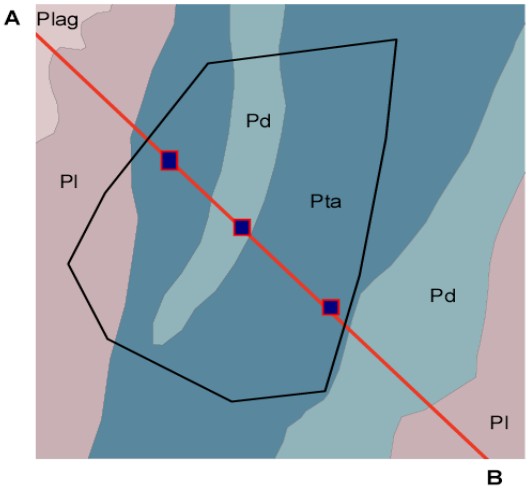


Erob TA1 – geological cross-section



Erob TA1 – conceptual model





Lithology

Pd	Didikama Formation- Dolomite interbeded with slate
Pta	Araequa Formation- undifferentiated Slate, Phyllites, Calcareous Sediments, limestone
Plag	Quartz porphyry sill with in upper part of Tsaliet Group
Pl	Tsaliet Group-Intermidiate and basic lavas, grey wack, tuffaceous slate, phyllite, agglomerate, rhyolite

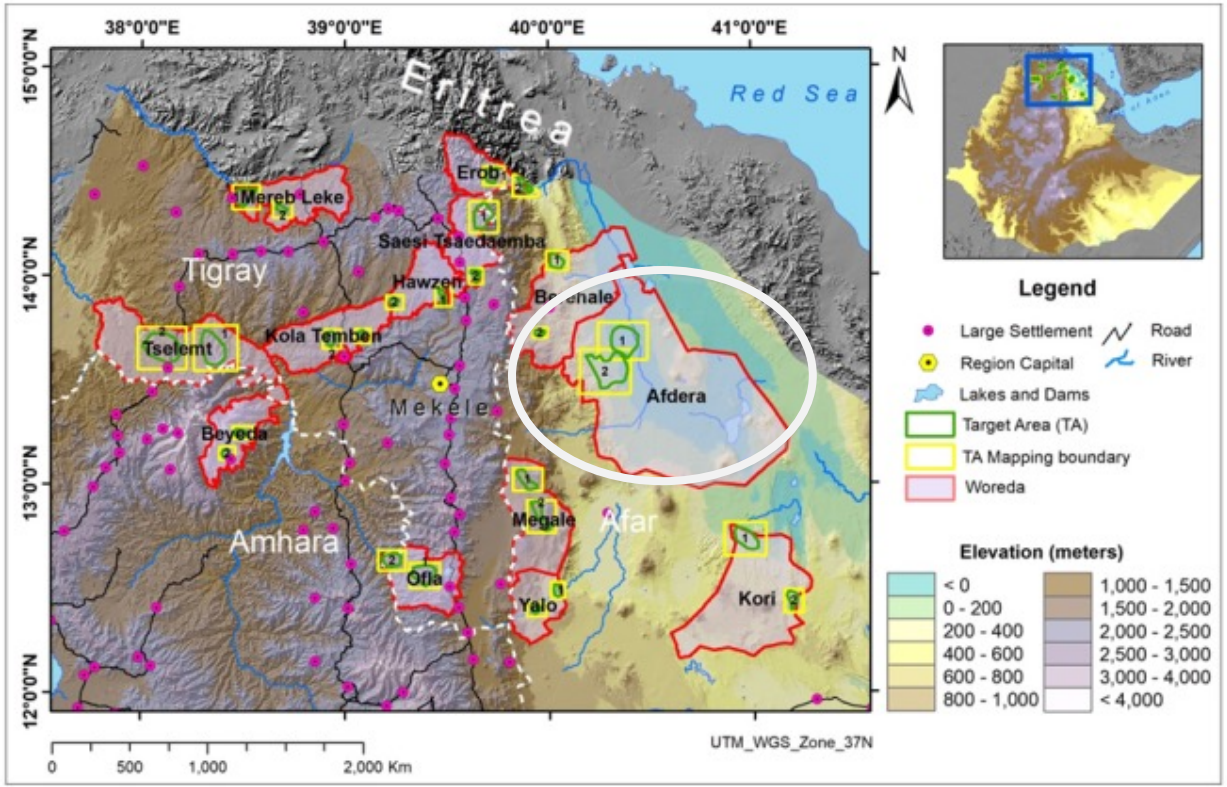
Geologic Structures

Normal Faults — Lineament

Other Symbols

Target Area — Proposed drilling site

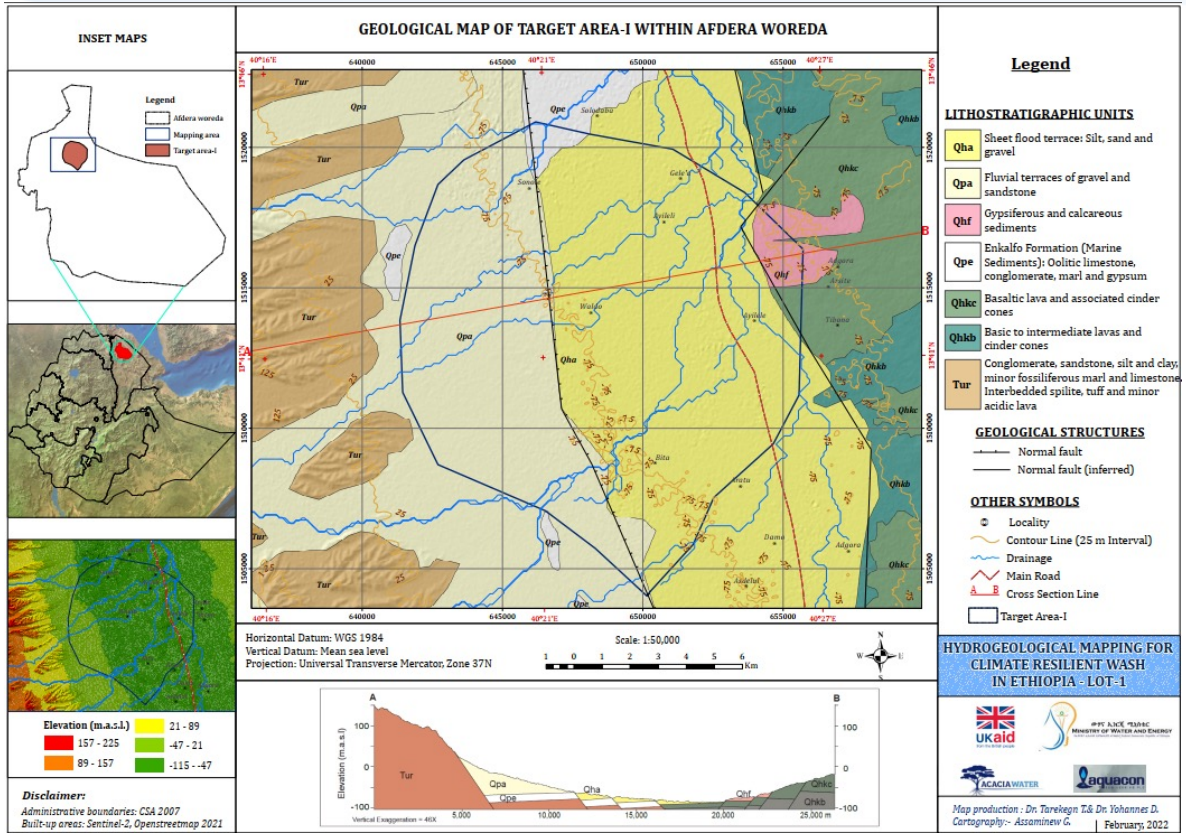
Afar - TA Afdera



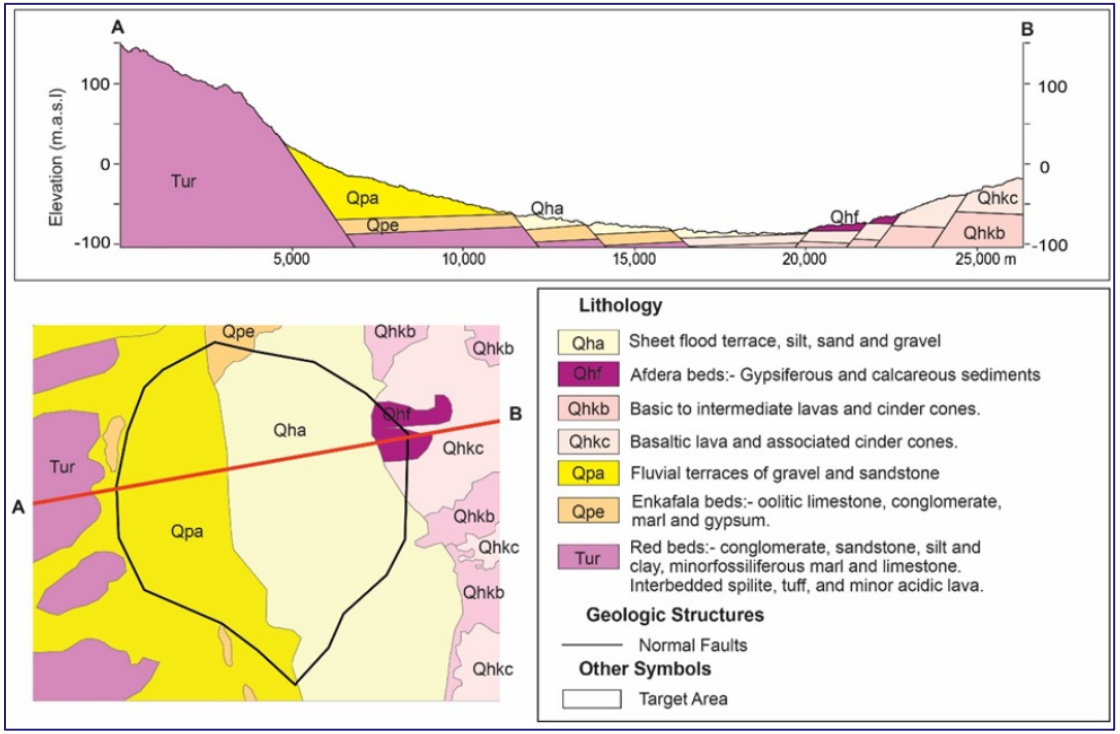
Afdera TA1 – Hydrogological characteristics

SN	Target Area code	Region	Zone	Woreda	Kebele	Center X	Center Y	Area (km^2)
1	AF1	Afar	Zone 02	Afdera	Ayitura	656516	1506757	104
Moderately productive porous aquifers where groundwater flowing to the northeast is accumulated by barrier of central massif of Erta Ale and can be developed by shallow and deep wells. Groundwater is hard with TDS between 1000 and 2000 mg/l, however content of sulphate and fluoride can be above standards for drinking water.								

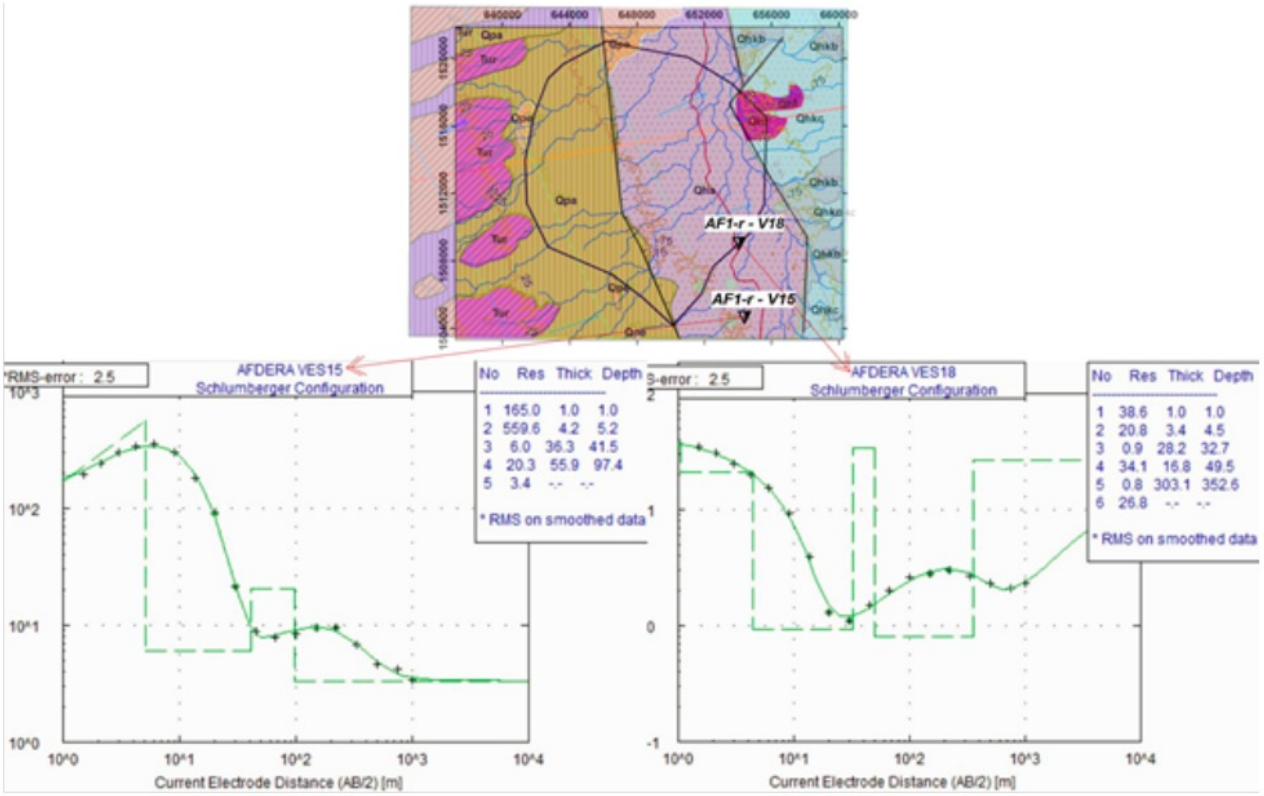
Afdera TA1 – Geological map



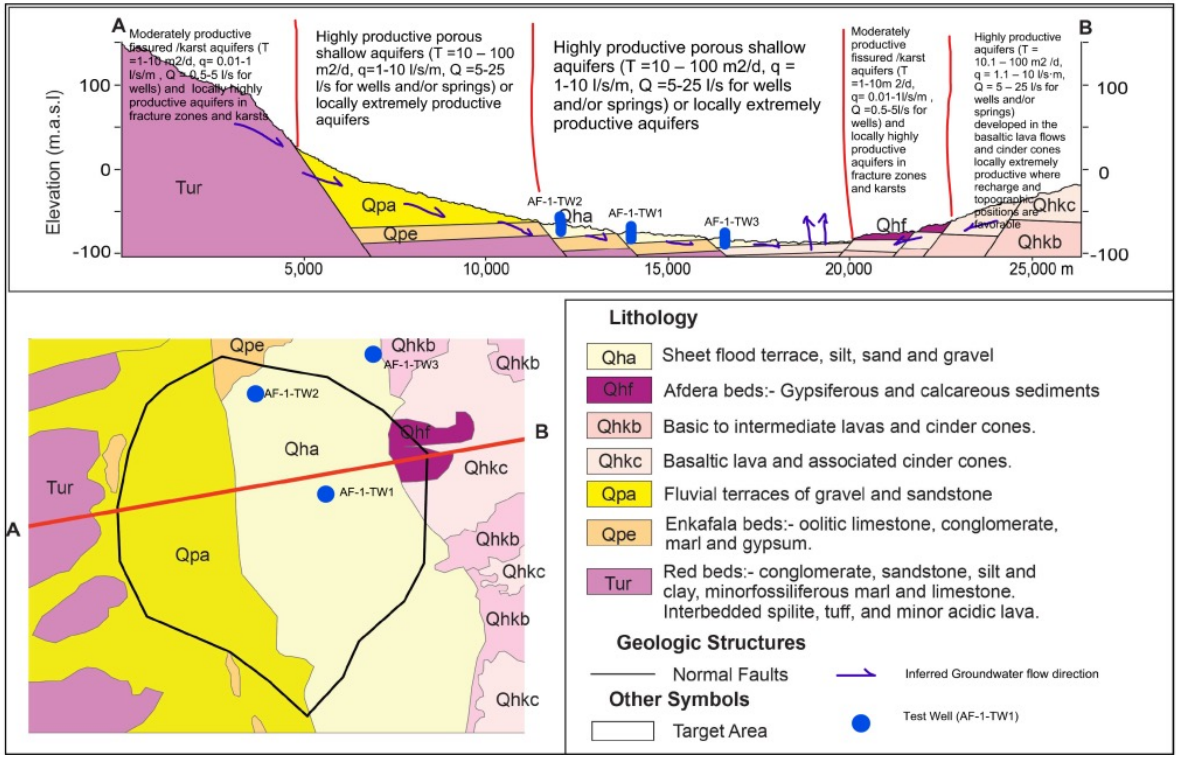
Afdera TA1 – Geological cross-section



Afdera TA1 - VES



Afdera TA1 - Hydrogeoloy



Examples of secondary data

Existing data – well data

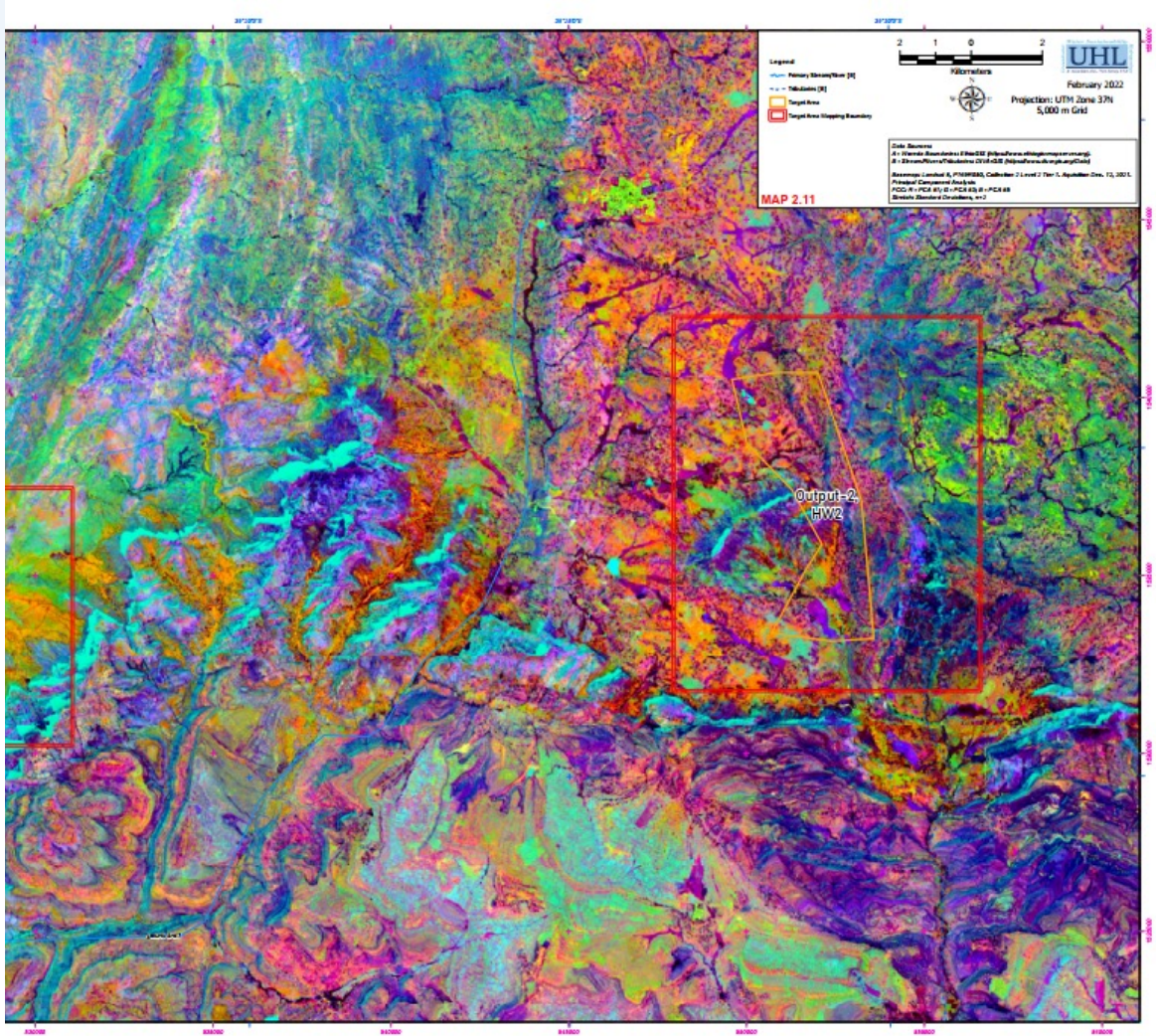
Woreda/region	Wells
Afar	**51**
Afdera	26
Berehale	17
Kori	1
Megale	3
Yalo	4
Amahara	**51**
Beyeda	51
Tigray	**3796**
Erop	251
Hawzen	1136
Kola Temben	256
Mereb Leha	375
Ofla	393
Saesi Tsadamba	1218
Tselemt	167
Grand Total	**3898**

Woreda/region	Springs
Afar	**42**
Afdera	11
Berehale	19
Megale	2
Yalo	10
Amahara	**89**
Beyeda	89
Tigray	**501**
Erop	39
Hawzen	96
Kola Temben	53
Mereb Leha	4
Ofla	139
Saesi Tsadamba	73
Tselemt	97
Grand Total	**632**

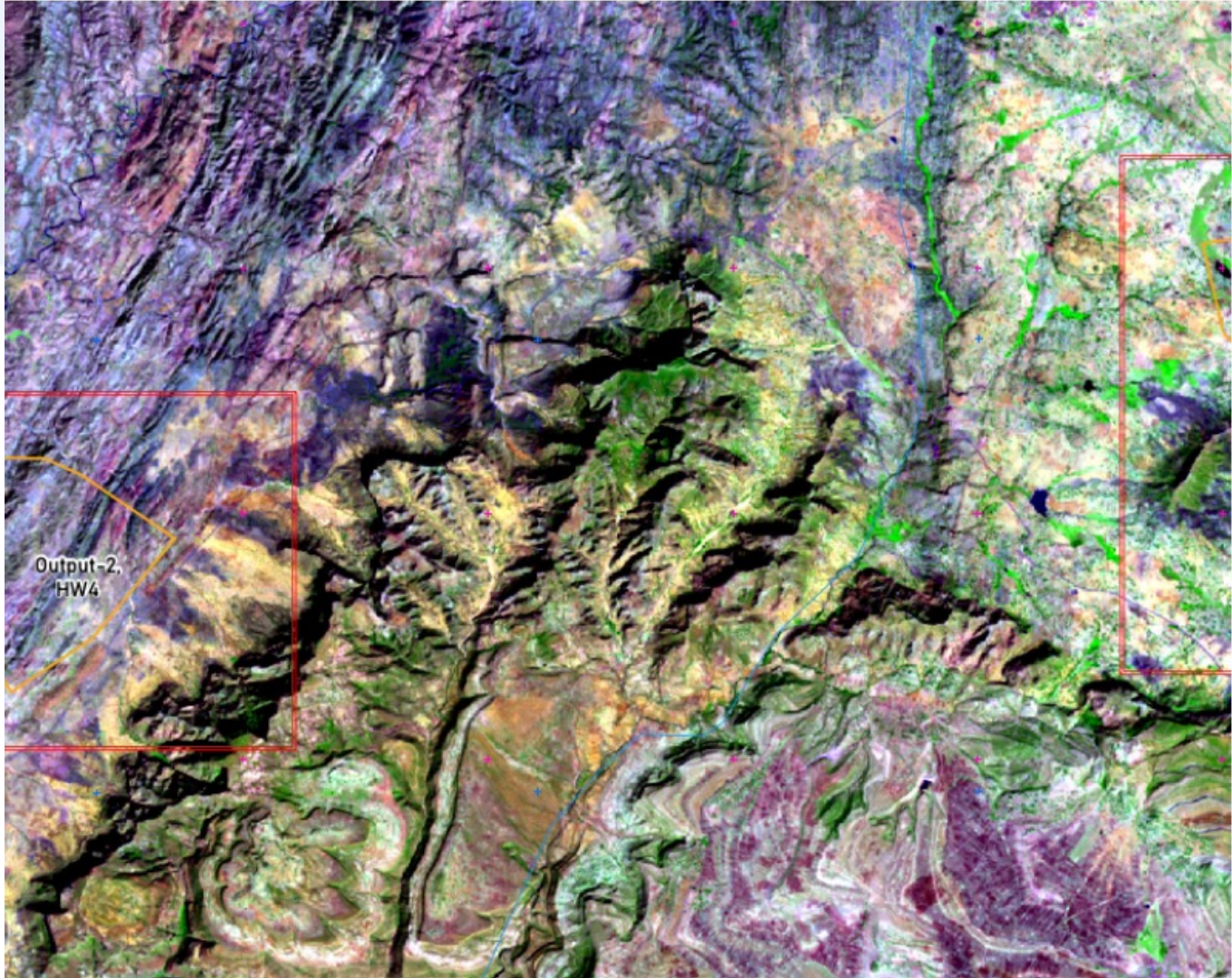
Satellite imagery

- Multispectral imagery
- Radar, soil moisture, water content products
- Lineament detection
  - Manual (photographs, Google Earth)
  - Automatic (Radar, Multispectral imagery)

Example of PCA, used as reference for geological interpretation



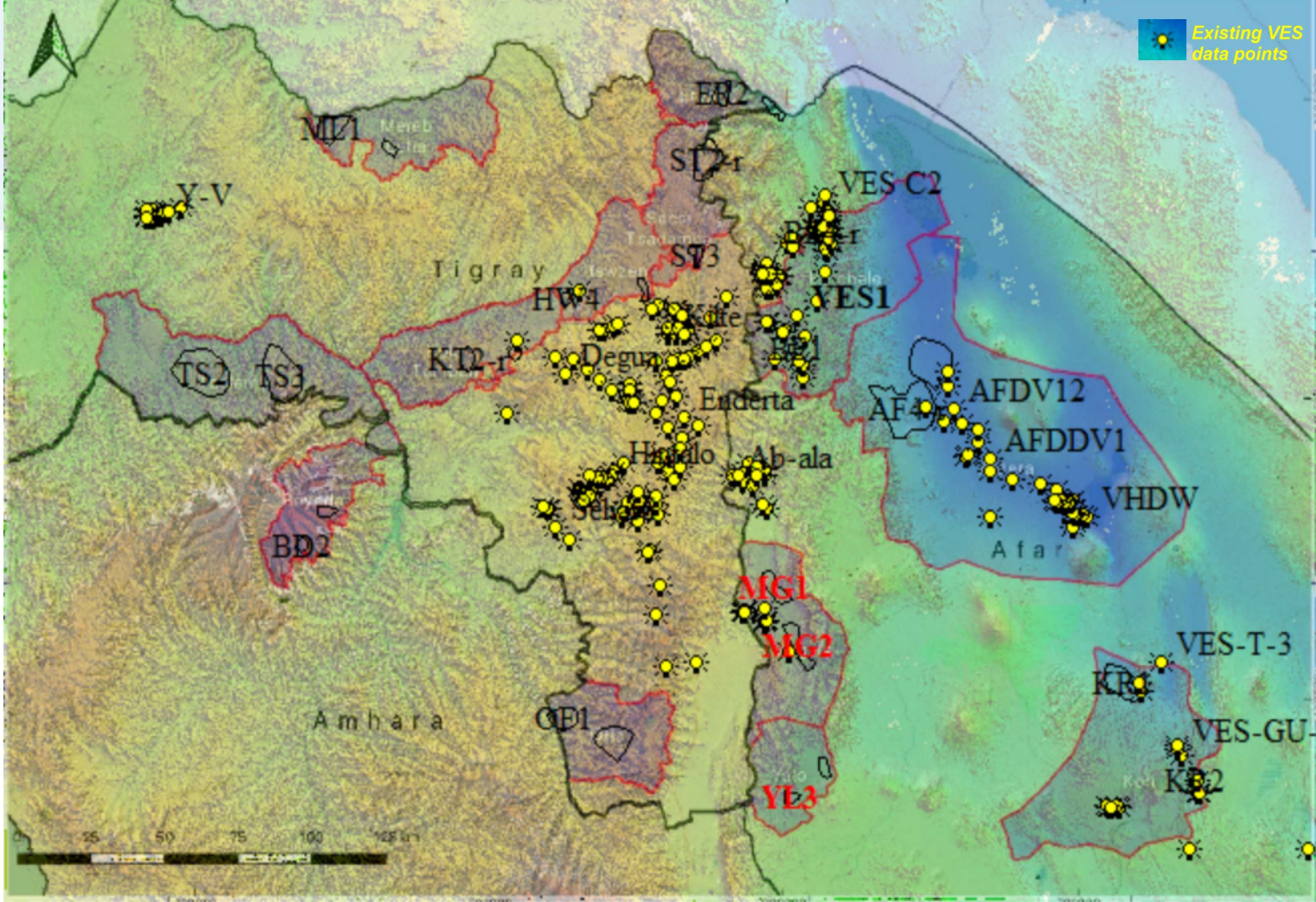
Multispectral imagery classification for geological mapping



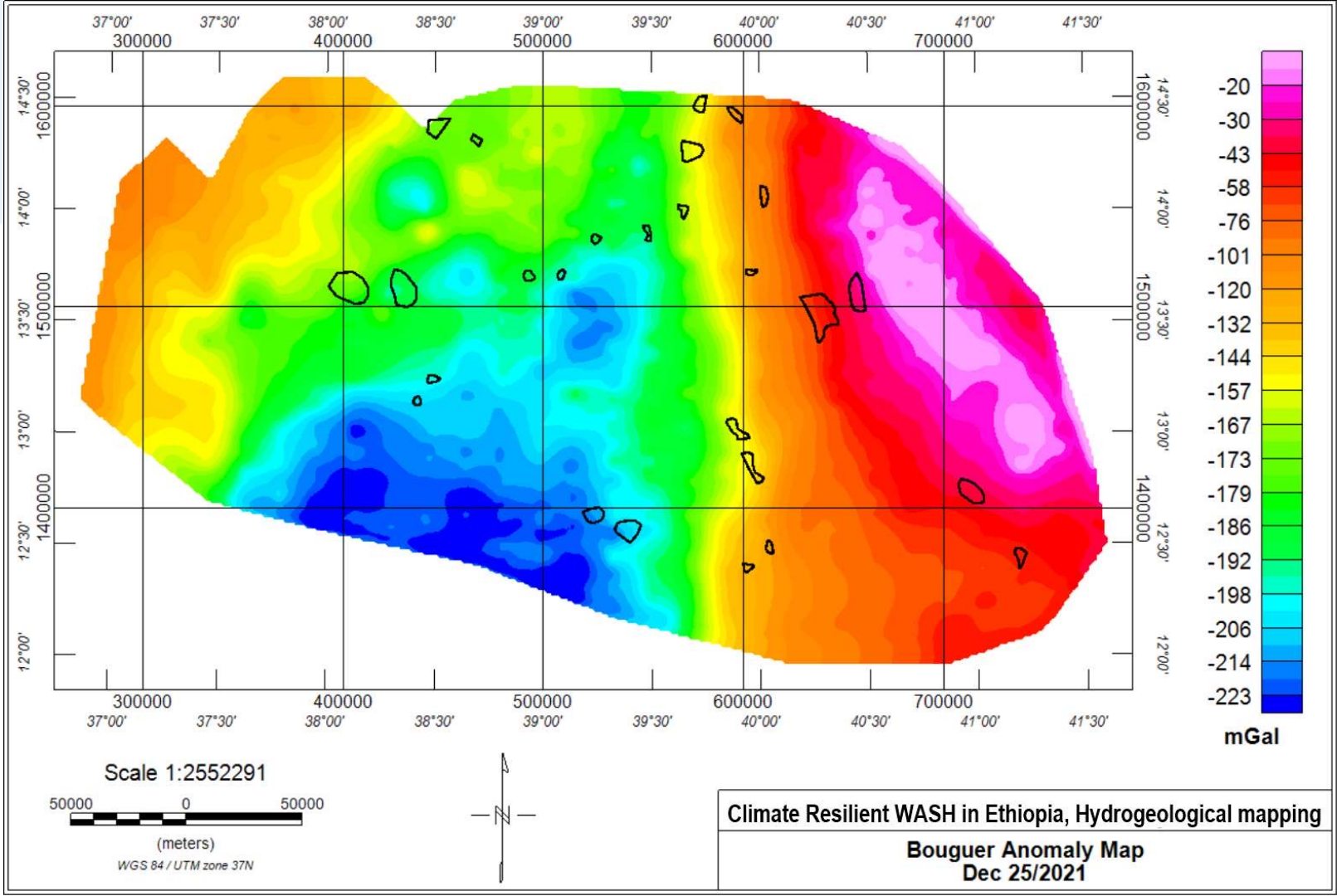
Airborne geophysics

- Geological Survey
  - Gravimetry
    - Deeper aquifers
    - Main structures
  - Magnetometry
    - Main fault lines, lineaments and intrusives
- Mining industry
  - Quite some (airborne) surveys done
  - Not readily accessible

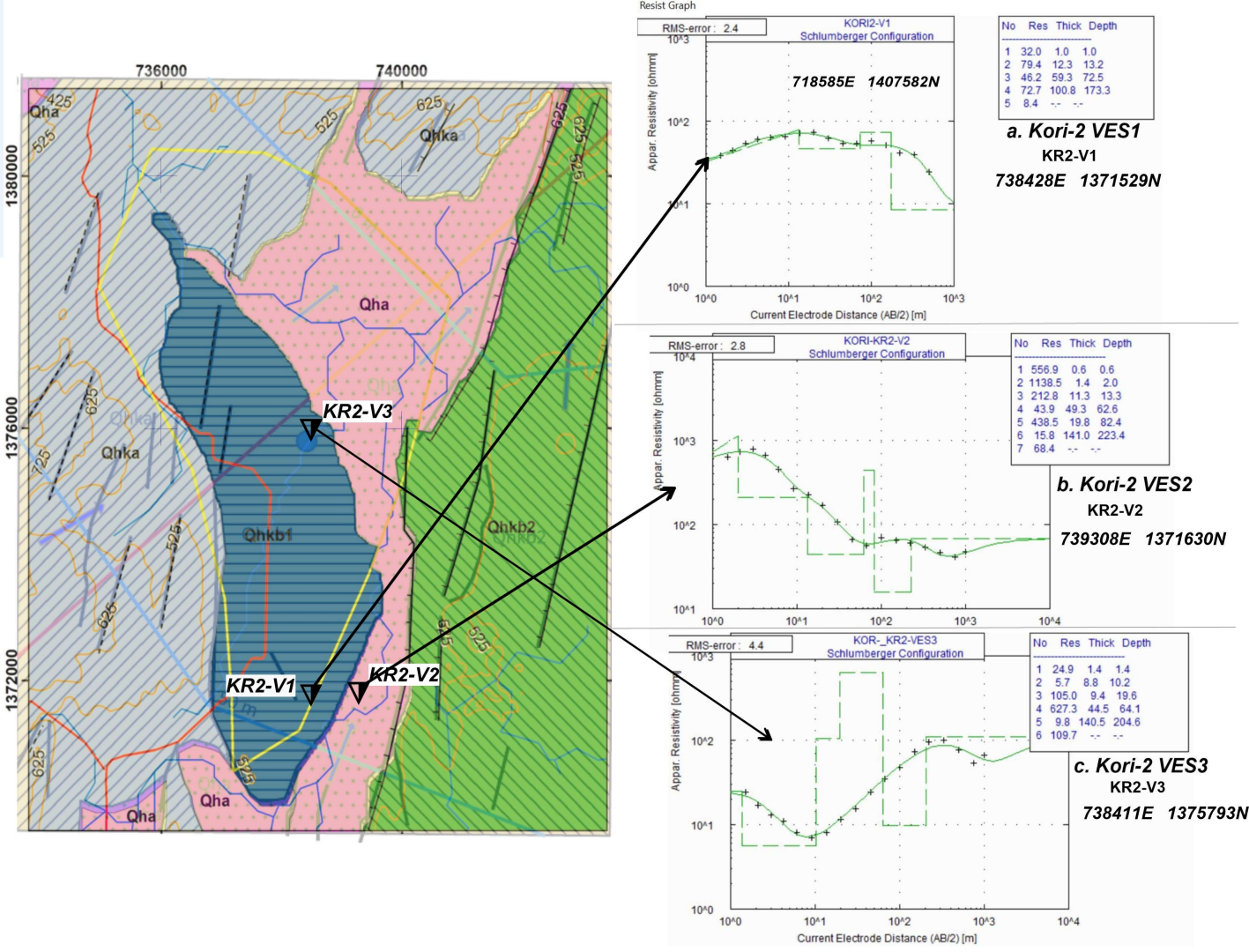
locations of existing VES data which part of it is used in the present study



gravity anomaly map of the study area



relative positions of the three VES points and their corresponding model parameters.



Examples of drilling site maps

Drilling sites

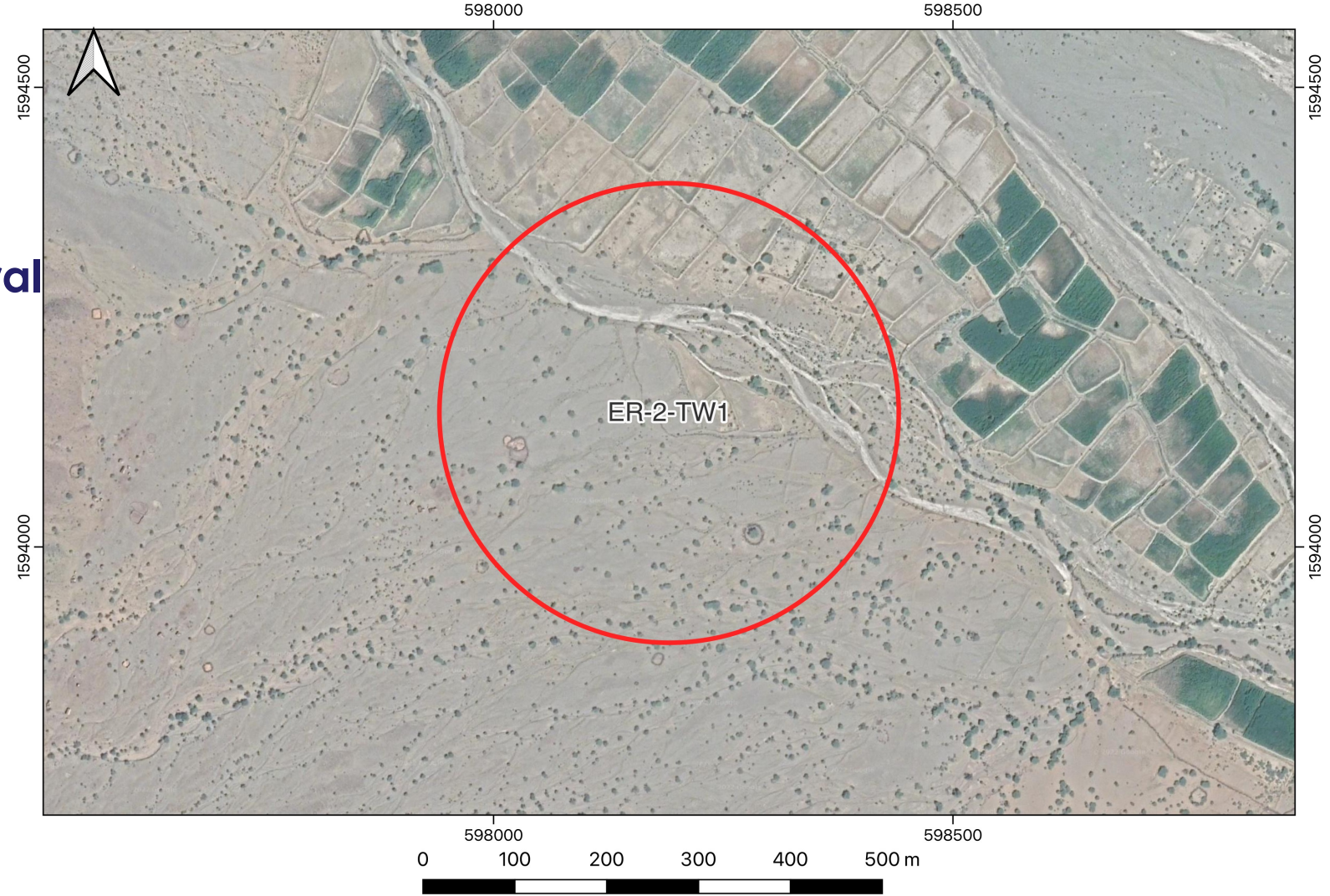
- Due to the security constrains no fieldwork
- Essential for updates on the actual water demand and gap analysis, geological and hydro-geological conditions, and geophysical surveys

target sites with a certain tolerance radius (250m)

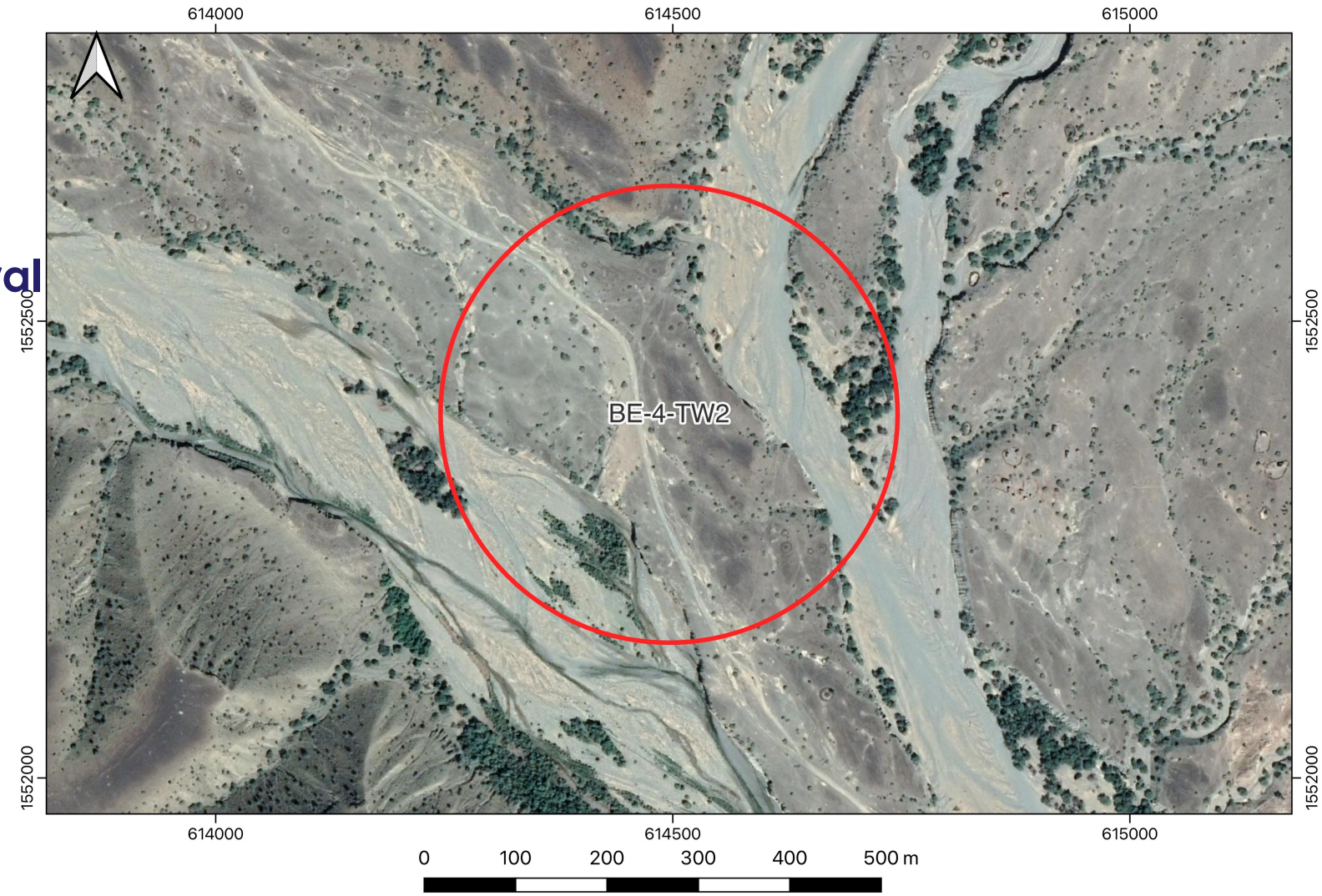
no exact drilling sites locations!

Region	Woreda	Target Area	Reference ID	x (km)	y (km)
Afar	Afdera	AF-4	AF-4-TW1	645	1505
Afar	Afdera	AF-4	AF-4-TW2	649	1496
Afar	Afdera	AF-1	AF-1-TW1	642	1510
Afar	Afdera	AF-1	AF-1-TW2	637	1522
Afar	Berhale	BE-4	BE-4-TW1	612	1554
Afar	Berhale	BE-4	BE-4-TW2	614	1552
Afar	Berhale	BE-1	BE-1-TW1	604	1519
Afar	Berhale	BE-1	BE-1-TW2	605	1517
Amhara	Beyeda	BD-1	BD-1-TW1	445	1464
Amhara	Beyeda	BD-1	BD-1-TW2	447	1465
Amhara	Beyeda	BD-1	BD-1-TW3	447	1453
Amhara	Beyeda	BD-2	BD-2-TW1	438	1453
Amhara	Beyeda	BD-2	BD-2-TW2	436	1453
Amhara	Beyeda	BD-2	BD-2-TW3	437	1453
Tigray	Erob	ER-4r	ER-4r-TW1	558	1601
Tigray	Erob	ER-2	ER-2-TW1	598	1594
Tigray	Hawzen	HW-2	HW-2-TW1	552	1534
Tigray	Hawzen	HW-4	HW-4-TW1	525	1532
Tigray	Kola Tembian	KT-3	KT-3-TW1	509	1518
Tigray	Kola Tembian	KT-2r	KT-2r-TW1	493	1511
Afar	Kori	KR-1	KR-1-TW1	719	1405
Afar	Kori	KR-1	KR-1-TW2	712	1412
Afar	Kori	KR-1	KR-1-TW3	712	1409
Afar	Kori	KR-2r	KR-2r-TW1	712	1385
Afar	Kori	KR-2r	KR-2r-TW2	716	1385
Afar	Kori	KR-2r	KR-2r-TW3	714	1392
Afar	Megale	MG-1	MG-1-TW1	597	1435
Afar	Megale	MG-1	MG-1-TW2	594	1439
Afar	Megale	MG-2	MG-2-TW1	599	1428
Afar	Megale	MG-2	MG-2-TW2	601	1419
Tigray	Mereb Leke	ML-1	ML-1-TW1	444	1583
Tigray	Mereb Leke	ML-3	ML-3-TW1	468	1582
Tigray	Ofla	OF-2	OF-2-TW1	541	1390
Tigray	Ofla	OF-1	OF-1-TW1	521	1397
Tigray	Tseadamba	ST-2	ST-2-TW1	578	1581
Tigray	Tseadamba	ST-3	ST-3-TW1	570	1550
Tigray	Tselemt	TS-3	TS-3-TW1	429	1510
Tigray	Tselemt	TS-2	TS-2-TW1	407	1503
Afar	Yalo	YL-1	YL-1-TW1	610	1379
Afar	Yalo	YL-1	YL-1-TW2	614	1380
Afar	Yalo	YL-2	YL-2-TW1	598	1369
Afar	Yalo	YL-2	YL-2-TW2	604	1371

Multispectral Erob TA2 drilling site



Multispectral Berehale TA4 drilling site



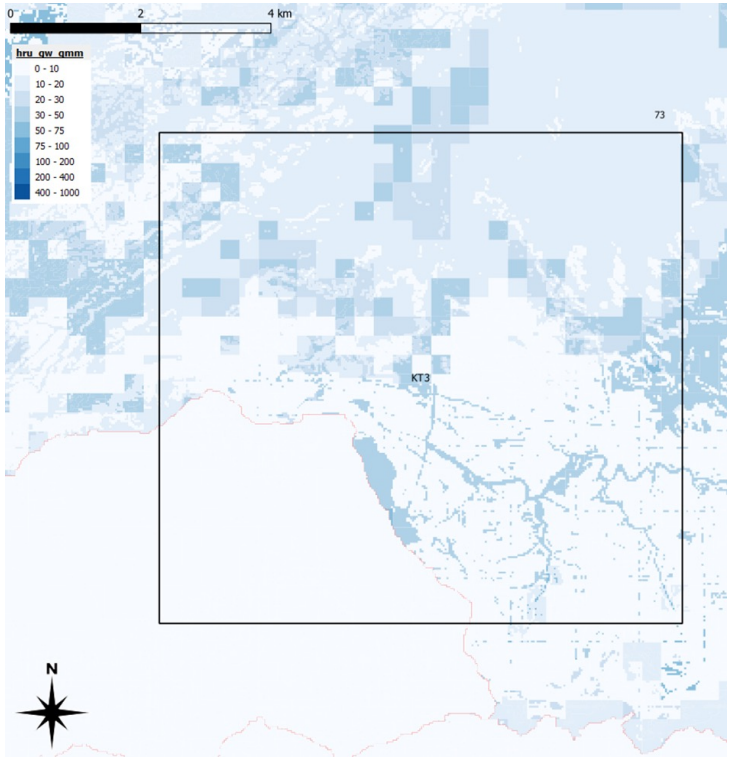
Recharge, water use and Resilience

Precipitation, recharge, demand and water scarcity

- Precipitation seems to be a dominant factor determining recharge
- Values in mm mo^{-1} or y^{-1}
- Target area Kola Temben 3 (KT3)
- Water scarcity index (WSI) is ratio of demand and availability (<40%)
- High irrigation demand dry season, not sustainable

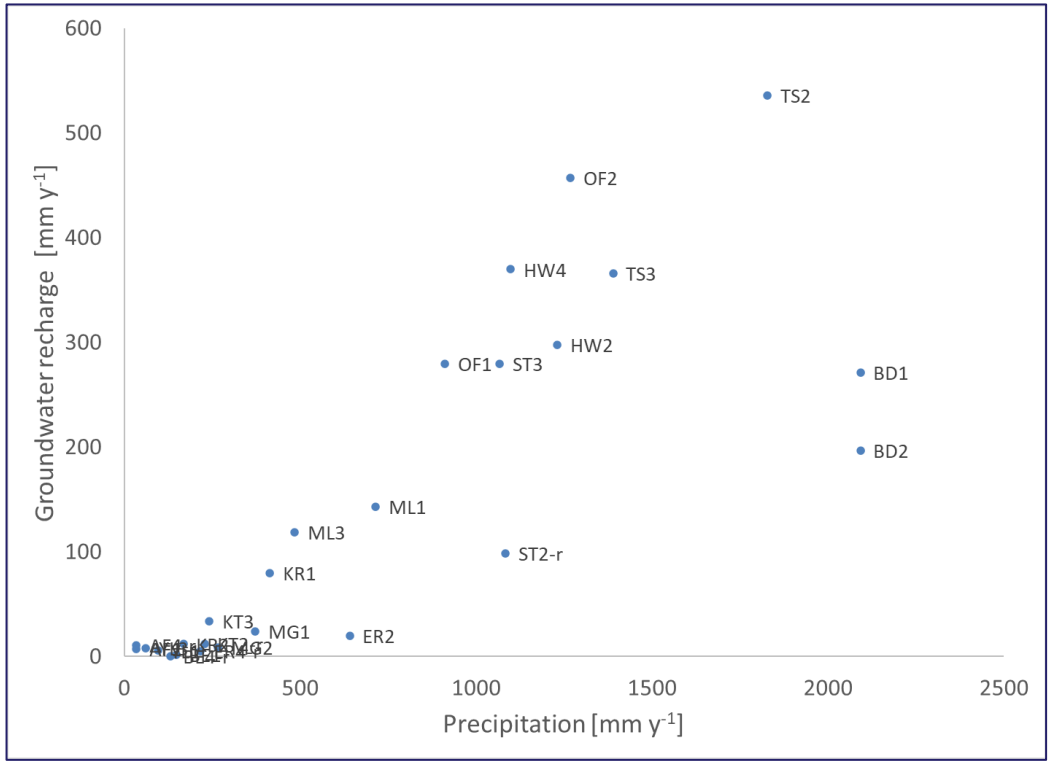
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rain	0.3	0.0	0.3	2.9	2.1	10.4	111.2	104.9	6.5	2.7	0.2	0.1	241.6
SURFQ	0.0	0.0	0.0	0.0	0.0	0.0	5.2	7.6	0.1	0.0	0.0	0.0	12.9
LATQ	0.0	0.0	0.0	0.2	0.2	0.4	8.2	10.8	2.3	0.5	0.2	0.1	22.7
WTYIELD	1.4	1.2	1.2	1.4	1.3	1.5	14.5	19.7	3.8	2.1	1.7	1.6	51.4
ET	3.2	2.7	3.0	4.2	2.9	7.2	40.0	54.1	31.2	14.1	6.1	3.7	172.4
PET	171	187	230	235	220	144	79	74	126	195	180	149	1991
EFR	0.3	0.3	0.3	0.3	0.3	0.4	3.6	4.9	1.0	0.5	0.4	0.4	12.8
Demand													
Domestic	0.130	0.119	0.130	0.126	0.130	0.126	0.130	0.130	0.126	0.130	0.126	0.130	1.534
Livestock	0.116	0.106	0.116	0.112	0.116	0.112	0.116	0.116	0.112	0.116	0.112	0.116	1.365
Irrigation	0.914	0.833	0.914	0.885	0.914	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.462
Industry	0.007	0.006	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.083
Total	1.168	1.064	1.168	1.130	1.168	0.245	0.253	0.253	0.245	0.253	0.245	0.253	7.443
WSI	84.0	90.2	94.2	83.7	90.5	16.1	1.7	1.3	6.4	12.1	14.7	16.2	14.5

Recharge KT3



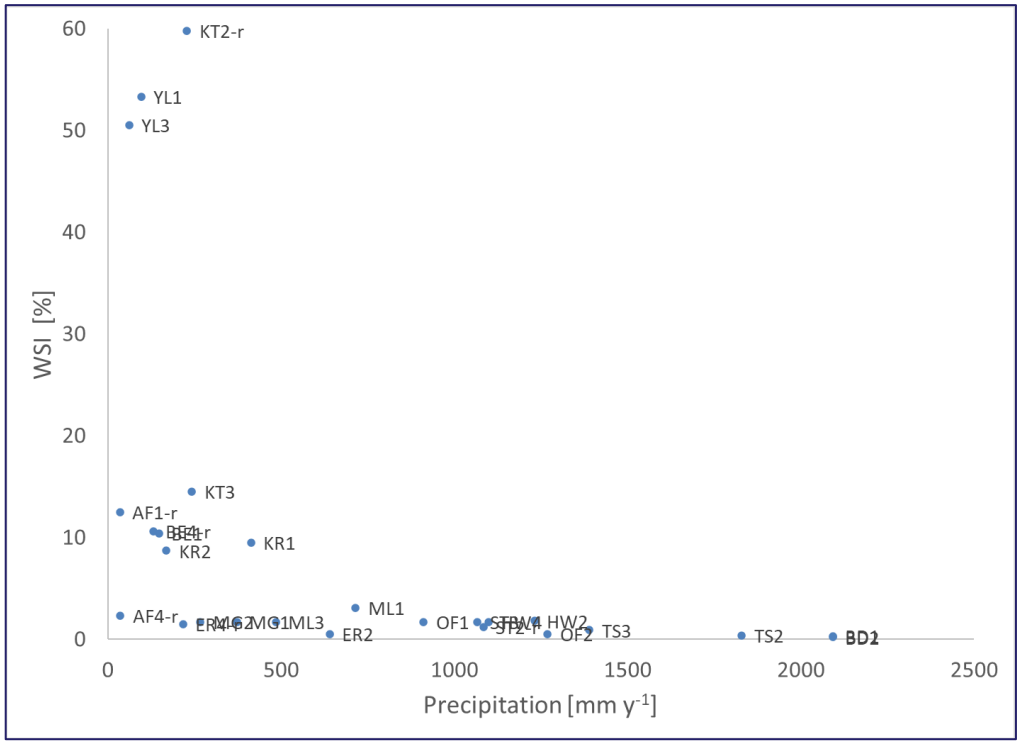
- Average areal precipitation 241 mm y^{-1}, lower is southern part
- Recharge < 10 mm y^{-1} in Southern part (rainfed agriculture / rangeland?)
- Up to 50 mm y^{-1} in river valleys and in Northern part (agriculture, irrigation?)

Precipitation and recharge



- If we display all target areas, it becomes clear that there is little recharge in areas below 400 mm y^{-1} precipitation
- Recharge increases with precipitation above 400 mm y^{-1}
- Water scarcity can easily develop in low rainfall areas

Water scarcity index and P



- Annual WSI is relatively low when P > 500 mm y-1
- However, if irrigation is practiced WSI in dry season may already exceed threshold value (40%)
- Careful planning needed to match demand to water resources availability
- Water harvesting and soil conservation important

Conclusions & recommendations

Conclusions

- In case of <400mm/y limited recharge
- Climate models suggest increased precipitation intensity
- SWC needed to enhance recharge
- Methodology focusses on potential for shallow groundwater

Recommendations

- Approach should be more regional, catchment based
- Development plan and demand mapping should be first step
- Water quality should be integral part of overlay analysis

Thanks for your attention

March 21th 2022

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